THE UNIVERSITY OF NEW SOUTH WALES
water
research
laboratory
Manly Vale N.S.W. Australia

GROUNDWATER MONITORING, EVALUATION AND GROWER SURVEY, NAMOI CATCHMENT

Report No. 2

PART A: RESULTS OF 2009 GROUNDWATER MONITORING AND RECOMMENDATIONS FOR FUTURE BEST PRACTICE MONITORING FRAMEWORK

PART B: GROUNDWATER USER SURVEY

by

W A Timms, A M Badenhop, D S Rayner and S M Mehrabi

Technical Report 2009/25
April 2010

THE UNIVERSITY OF NEW SOUTH WALES
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
WATER RESEARCH LABORATORY

IN ASSOCIATION WITH
GHD HASSALL

GROUNDWATER MONITORING, EVALUATION AND GROWER SURVEY, NAMOI CATCHMENT

Report No. 2

PART A: RESULTS OF 2009 GROUNDWATER MONITORING AND RECOMMENDATIONS FOR FUTURE BEST PRACTICE MONITORING FRAMEWORK

PART B: GROUNDWATER USER SURVEY

WRL Technical Report 2009/25 April 2010

by

W A Timms, A M Badenhop, D S Rayner and S M Mehrabi

https://doi.org/10.4225/53/58e1d814816e3

Water Research Laboratory
School of Civil and Environmental Engineering
University of New South Wales ABN 57 195 873 179
King Street
Manly Vale NSW 2093 Australia

Telephone: +61 (2) 9949 4488
Facsimile: +61 (2) 9949 4188

Technical Report No	2009/25
Report Status	Final
Date of Issue	April 2010
WRL Project No.	08085
Project Manager	W A Timms

Title	Groundwater Monitoring, Evaluation and Grower Survey, Namoi Catchment, Report No. 2 Part A: Results of 2009 Groundwater Monitoring and Recommendations for Future Best Practice Monitoring Framework Part B: Grower Survey
Author(s)	W A Timms, A M Badenhop, D S Rayner and S M Mehrabi
Reviewed by	B Kelly and B M Miller
Client Name	Cotton CRC and Namoi Catchment Management Authority
Client Address	
Client Contact	
Client Reference	

GLOSSARY OF TERMS

Baseline	Baseline conditions are the range of values that are representative of a system prior to a certain reference point eg. a new development or legislative date. By definition, values outside of baseline conditions can only occur if there has been a change to the system.
Benchmark	A standard or point of reference by which progress can be measured. In this report, the benchmark aims to reflect the baseline conditions of the catchment.
Beneficial use	The purpose for which water may be used as governed by the quality of the water. Also defined as ‘environmental value’ in the NSW Groundwater Protection Policy (DLWC,1998); beneficial uses may include ecosystem protection, recreation and aesthetics, raw water for drinking water supply, agricultural water, and industrial water.
BMP	Best management practice
Catchment Target	Catchment Targets are “a statement of future goals about the desired condition of the resource” providing a “broad indicator of catchment health” (Namoi CMA, 2007).
CMA	Catchment Management Authority
CWI	Connected Waters Initiative http://www.connectedwaters.unsw.edu.au/
DECCW	Department of Environment, Climate Change and Water (formerly Department of Water and Energy, DWE)
DO	Dissolved oxygen
EC	Electrical Conductivity
GDE	Groundwater dependant ecosystem
GWMA	Groundwater Management Area, also referred to as Groundwater Management Unit, GMU
SAR	Sodium Adsorption Ratio
SWL	Standing water level
TDS	Total dissolved solids
Trigger	A *trigger* is a means of defining whether change has occurred within a system, such that a management action is required or ‘triggered’. By this definition, a trigger is a methodology for determining significant change within a system. This methodology may include, but is certainly not limited to, setting a specific hard ‘*trigger value*’ that cannot be exceeded.
UCL	Upper Cutoff Limit – a type of trigger that can be used as hard limit; above this value a management action may be triggered.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Monitoring of groundwater levels and groundwater quality is essential to ensure that this resource continues to be the life blood of the Namoi catchment and communities. Low salinity groundwater must be maintained at levels that are accessible for the environment, drinking water supplies, stock water and for irrigation, supporting an industry worth at least $380 million each year. This project has helped define how groundwater levels and salinity vary both spatially and temporally within the catchment. Data sets used for the analyses were both historical and newly collected from production bores and key state government groundwater monitoring bores.

The project was completed by the Water Research Laboratory (WRL) projects team of the University of New South Wales, in association with GHD Hassall, on behalf of the Cotton Catchment Communities CRC and the Namoi Catchment Management Authority. Groundwater samples were collected by 79 growers from their production bores and WRL staff sampled priority state government groundwater monitoring bores in January, March and July 2009. Standard protocols were used to test ~60 samples at 45 bores on each occasion with a total of 189 field parameter records and 121 major ion analyses.

It was found that groundwater recovery levels each season remain relatively low compared to pre-extraction levels in many areas, although there are signs that drawdown levels have stabilised in other areas since 2006. Groundwater level drawdown appears to have stabilised in Zone 3 of the Upper Namoi and the unconfined aquifer of Cox's Creek. Groundwater salinity was relatively stable at most sites where sufficient historic data was available (105 monitoring pipes), however, significant groundwater salinity increases have occurred over the past two decades at about 20% of sites. Freshening had occurred at about 25% of sites that had sufficient data over the same period. However, it is of concern that some sites in Zone 3 of the Upper Namoi have become significantly more saline, some of which exceeded guideline values. The worst case was a 123% EC increase up to 2009 with groundwater at 80 m depth that had become too saline for irrigation of cotton. Yet groundwater in grower bores several kilometres away was found to be fresh, so further investigation of this finding is required.

A risk assessment of groundwater resources in the Namoi identified four areas where changes in salinity might occur in the future that require strategic monitoring. Available information including the distribution of salt stores in shallow sediments, indicates that the groundwater resource is at risk in areas of high usage in parts of the Upper Namoi alluvium (Zone 3 and 8) and Lower Namoi alluvium (north of Wee Waa and near Wee Waa). There

is currently insufficient baseline groundwater quality data to establish robust trigger values, although in the interim a >10% EC increase in a bore would provide an early warning indicator of changes.

Interviews and workshops were used to survey grower attitudes, identifying a priority need to improve communication of groundwater information, particularly at the start of each irrigation season. The survey also found a widespread interest in developing and promoting protocols for groundwater users to gather and track their own groundwater data. Another priority recommendation was to supplement NSW Office of Water data with additional independent monitoring of groundwater quality. Most groundwater users had a good to reasonable understanding of groundwater issues but a limited knowledge of the current condition of the resource. Some growers expressed a desire for real-time data, such as the new telemetry program by NSW Office of Water if real time data for local areas can be accessed through the web. A community program for groundwater monitoring may be successful in some areas, although there were reservations expressed regarding how data might be used and the reliability of data. Recommendations of the grower survey and workshops focused on improving the communication of information about groundwater conditions and promoting groundwater users to gather and track their own groundwater quality and levels.

In response to this feedback, the project further developed strategic monitoring guidelines with a 4 level Best Management Practice (BMP) for irrigation bore monitoring and a 3 level guideline for subcatchment and regional scale. The BMP for irrigation bores will form part of the myBMP program for the Cotton Catchment Community CRC. For example, a level 2 BMP is to maximise crop yields by using bore water within appropriate salinity guidelines. On a regional scale, the current standard at which the monitoring of groundwater levels is collected and reported is satisfactory for examining long term trends in water levels. There is a small existing program to upgrade some of the monitoring network to a telemetry system. This report supports the new telemetry project and suggests it should be extended. There is also a need for new monitoring of groundwater zones within the catchment not impacted by irrigation extractions for examining in influence of climatic variability and change on groundwater recharge. However, regular monitoring of groundwater quality is currently limited to field parameters and major ion data at a few locations at an estimated cost of $40,000 to $80,000 per year.

To date the monitoring of water quality has been irregular, making statistical analysis difficult. It is recommended that the standard of groundwater quality monitoring is strategically increased to at least a moderate practice at an estimated cost in the order of

$100,000 to $200,000 per year. A moderate standard of groundwater quality monitoring would include testing of field parameters (standing water level, electrical conductivity, pH and temperature) and major ions at approximately 60 key monitoring pipes twice per year, focused in areas where salinity increases have occurred, or may occur in the future. An enhanced moderate standard with quarterly testing would improve confidence levels of statistical baseline parameters, at a cost of approximately $200,000 to $300,000 per year. These monitoring costs compare with an estimated $480,000 per year of groundwater access and usage fees for users of the Namoi alluvium sources. A high standard of groundwater quality (which has not been costed) would include more widespread testing in areas of the catchment that do not currently have monitoring infrastructure, and could include other water quality parameters such as nutrients.

Investing in strategic groundwater quality monitoring by individual growers and at a regional scale is vital to ensuring continued access to fresh groundwater resources by all users including the environment. Strategic groundwater quality monitoring is a critical component of the total investment in monitoring, investigating, modelling and managing groundwater resources across the entire Namoi catchment.

PART A:

RESULTS OF 2009 GROUNDWATER MONITORING AND RECOMMENDATIONS FOR FUTURE BEST PRACTICE MONITORING FRAMEWORK

1. INTRODUCTION

The Namoi region of north-eastern NSW is based around the Namoi, Manilla and Peel Rivers and contains the major regional centres of Tamworth, Gunnedah, Narrabri, Boggabri and Wee Waa (Figure 1). Groundwater resources are mostly sourced from deeper alluvial deposits associated with the main rivers and prior streams; these are often overlain with relatively saline or brackish waters. Groundwater in the Namoi catchment supports an irrigation industry worth in excess of $380 million as well as being the water supply for many towns and intensive industries such as feedlots. Groundwater resources in the region are the most intensively developed in NSW (CSIRO, 2007) with 2004/2005 groundwater extraction of 255 GL. Lake Goran is the only wetland of national significance in the area.

Monitoring the status of groundwater levels and groundwater salinity is central to groundwater management. To better understand this, the Cotton Catchment Communities CRC (Cotton CRC) and Namoi Catchment Management Authority (Namoi CMA) have commissioned this project which aims to:

- Establish a framework for benchmarking groundwater quantity and quality in the Namoi which will form the basis of future assessment
- Understand how the condition of the catchment varies over time and across the region and to utilise this information to improve the management of groundwater resources in the Namoi.

Report 1 (WRL Technical Report 2009/04, 2009) reviewed the current literature regarding the Namoi catchment groundwater and provided an assessment of the groundwater monitoring framework of the area. The key issues of concern identified in this report were decreasing groundwater levels and salinisation of groundwater. This report should be referred to for background information on the catchment.

As a result of the review undertaken for Report 1, this report (Report 2) provides a review of approaches to groundwater indicators and catchment targets and outlines the results of the groundwater monitoring program undertaken as part of this project. The key risks to groundwater identified as part of this project are documented, followed by recommendations for groundwater monitoring in the future.

1.1 Scope of Work

This project builds on the Namoi CMA State Monitoring and Evaluation Programme, current monitoring by the Department of Environment, Climate Change and Water (DECCW, formerly Department of Water and Energy, DWE) and various groundwater projects around the catchment. This project helps to meet the goals and milestones of the Cotton CRC's Catchment and Communities program. The monitoring data evaluation helps meet the Namoi CMA's Catchment Action Plan and resource management targets.

The broad scope of work completed includes the following:

- Review, collation of information and targeting of monitoring strategies (WRL Technical Report 2009/04, Report No. 1)
- Consultation with stakeholders including Namoi water users
- Groundwater level and salinity data collection from representative monitoring bores (in January, March and July 2009)
- Build capacity for groundwater users to participate in monitoring
- "Groundwater Testing" by growers in July – planning, promotion and implementation
- Design and implement a grower survey on attitudes and perceptions and deliver a discussion paper on grower attitudes, perceptions and enhancing participation
- Produce groundwater maps showing groundwater levels and quality
- Report on future strategic sampling approach and risks to beneficial uses, develop guidelines for implementing best practice monitoring and report on early warning indicators of the condition of groundwater resources and better managing catchment targets
- Stakeholder workshops in the Upper and Lower Namoi catchments
- Dataset and references provided for the Namoi CMA information system and DWE databases
- Report No. 2 (WRL Technical Report) with all review findings, evaluations, recommendations and a database on CD-ROM.

1.2 Report Structure

Part A of this report is divided into six sections. After this introduction, Section 2 gives a literature review of approaches to groundwater indicators for managing catchment management targets, including beneficial uses of groundwater and means to determine significant changes in groundwater. Section 3 introduces the connectivity method for defining and mapping aquifer units. Section 4 documents the methods and results from the groundwater sampling in July program and the monitoring bore sampling program. Using a combination of data collected for this project and historical data, Section 5 discusses the risks to groundwater in the Namoi catchment, while Section 6 updates and builds on the recommendations for a groundwater monitoring program outlined in Report 1. A summary and conclusions are given in Section 7.

Part B of this report documents the method and results for a grower survey on attitudes and perceptions and deliver a discussion paper on grower attitudes, perceptions and enhancing participation.

2. REVIEW OF GROUNDWATER INDICATORS AND TARGETS

This Section reviews approaches to groundwater condition indicators in the context of catchment management targets.

The Namoi Catchment Management Authority (CMA) catchment action plan (Namoi CMA, 2007) is a framework for guiding natural resource management in the Namoi catchment. This report is concerned with one of the four key regional resources identified in the plan, that of "Surface and Ground Water Ecosystems". For each resource identified, there is one Catchment Target regarding the status of that resource. The Catchment Target for Surface and Ground Water Ecosystems is:

"From 2006, there is an improvement in the condition of surface and ground water ecosystems."

The intent of this target is to "achieve the vision of being a viable and sustainable region" by "maintaining or improving water quality and providing access" (i.e. beneficial use) for all users including the environment, while the productive uses of the catchment providing regional wealth are maintained (Namoi CMA, 2007).

In order to ensure that water quality is either maintained or improved, it is necessary firstly to define or benchmark the baseline water quality of the catchment, and then to determine whether there is any change in water quality through monitoring. While this concept is straightforward, there may be many obstacles to achieving this goal. Benchmarking water quality is difficult with data limited both temporally and spatially, and there are no agreed methodologies for determining either if there has been any change in water quality, or what the significance is of that change i.e. if that change should trigger an action.

To achieve the Catchment Target of "improving the condition of surface and ground water ecosystems", corresponding Management Targets were set in the catchment action plan (Namoi CMA, 2007). Section 2.1 outlines the catchment management targets relevant to this project. Section 2.2 describes beneficial uses for groundwater as a means to define or benchmark the ground water quality of the catchment. Section 2.3 outlines ways of monitoring ground water to achieve targets.

2.1 Catchment Management Targets in the Namoi

To achieve the Catchment Target of "improving the condition of surface and ground water ecosystems", there are corresponding Management Targets. This project is primarily related to the following two catchment management targets:

Surface and Ground Water Quality, including River Salinity
MTW2 – From 2006, maintain or improve surface and ground water quality suitable for irrigation, raw drinking water and aquatic ecosystem protection at Gunnedah, Narrabri and Goangra. Target values are as determined by:

a) Australian & New Zealand Environmental Conservation Council Guidelines 2000, for Irrigation Water - Electrical conductivity range of 650 –1300µS/cm; and Aquatic Ecosystem Protection - mean values of Total Endosulphan < 0.03 µS/Litre and Atrazine < 0.7 µS/Litre.

b) MDBC; River Salinity of 550 µS/cm 50% of the time and < 1000 µS/cm 80% of the time at Goangra (at time of writing the CAP).

This will be achieved by the following management actions:

a) rehabilitating the riverine ecosystem;
b) minimising pollution from point sources discharges such as industry;
c) minimising diffuse source pollution by better land management practices;
d) protecting groundwater from contamination by salts and pesticides through managing extractions, leaching and bore head contamination; and
e) improving river flow and availability of adaptive environmental water.

Water Management Plans
MTW4 - From 2006, oversee and review water management planning and other processes under the Water Management Act 2000, so that Water Management Plans, including Water Sharing Plans (WSPs), result in fair and reasonable access to surface and ground water sources for the environment (water dependant ecosystems), economic uses (agricultural, industrial, town water supply) and social values (recreation, cultural).
This will be achieved though:

a) water sharing plans;
b) consultative processes;
c) adaptive environmental water management;
d) major infrastructure upgrades;
e) operations of major dams eg. management of water quality impacts, including pollution from cold water; and
f) floodplain management and planning.

The first management target (MTW2) of maintaining or improving water quality from 2006 focuses on the need to be able to retain the beneficial use (e.g. irrigation, drinking water, aquatic ecosystem protection) of the water. The main indicator used to define that target is salinity in terms of electrical conductivity. To achieve this target, it is firstly necessary to define the beneficial use of the water prior to 2006. This is a means of benchmarking the water quality. Beneficial use categories for water based on quality are defined further in the following section, while an analysis of catchment specific data is found in Section 5.1. Any change in beneficial use may indicate the need for action; methods for determining whether monitoring shows significant changes are discussed in Section 2.3.

The second management target (MTW4) intends to achieve ecologically sustainable yield for groundwater sources which requires the maintenance of water quality objectives (as discussed in MTW2) and sustainable use of groundwater sources. Unsustainable use may be indicated by stressed aquifers showing ongoing decline in water levels. Methods for determining whether monitoring shows significant decline are discussed in Section 2.3.

2.2 Beneficial Uses for Groundwater

It is the policy of the NSW Government to encourage the ecologically sustainable management of the State's groundwater resources, so as to maintain the full range of beneficial uses of these resources. One of the management principles which ensures that the Policy objectives will be achieved is that "All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained". The NSW Groundwater Quality Protection Policy provides a framework for the sustainable management of groundwater quality through adopting a beneficial use classification system that will be the basis for setting water quality objectives for all groundwater systems in NSW (DLWC, 1998).

It is important to note that beneficial uses do not only include uses with commercial value, as the environment's share of water to remain healthy and completely sustained is considered one of the most valued beneficial uses.

In general terms groundwater can potentially have the same beneficial use as surface water. These uses cover four major areas:

- Aquatic ecosystems (in this case, groundwater dependent ecosystems or GDEs)
- Primary Industries
    - Irrigation and general water use
    - Livestock drinking water

  - Aquatic and human consumption of aquatic foods

- Recreational (where there is a base flow discharge into the surface water body)
  - Swimming and boating
  - Aesthetic appeal of water bodies

- Drinking water
  - Safety
  - Aesthetically pleasing.

This project will mainly focus on the common uses in the Namoi catchment including irrigation (with special attention to cotton), livestock, and human drinking water.

As the main indicator to define water quality in terms of suitability for each of the beneficial uses is salinity (measured by EC or TDS), the relevant guidelines were extracted from ‘The Australian and New Zealand Guidelines for Fresh and Marine Water Quality-2000” known as ANZECC (2000) and “Australian Drinking Water Guidelines” (2004) or ADWG (2004).

Table 1 contains the salinity guidelines for the most common beneficial uses in Namoi catchment.

Table 1
Salinity Guidelines for Key Beneficial Uses in the Namoi Catchment

	EC (µS/cm)	Comments	Source
Irrigation	8000	Unsuitable for barley irrigation.	ANZECC (2000)
	7700	Unsuitable for cotton irrigation.	
	5500	Unsuitable for sunflower irrigation.	
	6000	Unsuitable for wheat irrigation.	
	1500	If used on early season cotton, the final yields could be diminished.	
Livestock	14920**	Loss of production and a decline in beef cattle condition and health.	
	10450**	Loss of production and a decline in dairy cattle and horses condition and health.	
	11940**	Loss of production and a decline in pigs condition and health.	
	5970**	Loss of production and a decline in poultry condition and health.	
	19400**	Loss of production and a decline in sheep condition and health.	
Drinking Water***	<120*	Excellent drinking water quality.	ADWG (2008)
	120-750*	Good drinking water quality.	
	750-1200*	Fair drinking water quality.	
	1200-1490*	Poor drinking water quality.	
	>1490*	Unacceptable drinking water	

* TDS values converted to EC using equation: EC (µS/cm) x 0.67 = TDS (mg/L) (ANZECC, 2000)
** Note that if the TDS concentration is above 2400 mg/L, the water should be analysed to determine the concentrations of specific ions to avoid possible toxication (ANZECC, 2000)
*** Bruvold and Daniels (1990) in Australian Drinking Water Guidelines (2008)

While ecosystem health is an important beneficial use, it is difficult to define a single guideline value for salinity due to the natural variety of the biota and their various tolerance range for salinity. Setting guidelines for GDEs requires a comprehensive study in the region in which native fauna and flora are listed and assessed in terms of their tolerable range of water dependency, salinity, and other quantitative and qualitative conditions.

2.3 Monitoring Groundwater to Manage Catchment Management Targets

To determine if catchment management targets (as found in Section 2.1) are being met, groundwater monitoring data must be regularly collected and analysed. This analysis must ascertain whether recent ground water quality or level measurements indicate a significant change that requires a management action to be initiated i.e. an early warning indicator of undesirable change is needed.

At the same time, it is vital that natural variability within the system is recognised (through benchmarking or collecting baseline data) to prevent unnecessary alarm. This section investigates Australian and international approaches to defining triggers for action and statistical methods for analysing limited amounts of data. Note that it is outside the scope of this project to recommend management response should significant changes to water quality or levels be found.

2.3.1 Appropriate Triggers to Identify Significant Changes

Triggers are needed to identify significant changes in groundwater quality which may lead to the degradation of the groundwater's highest beneficial use. They must be established on the basis of baseline groundwater conditions, the physical and chemical characteristics of the indicator used, and potential aquifer recharge (potential dilution, or contamination if the recharge source is the contamination source).

Triggers must be sensitive enough to detect any trend potentially leading to a change of beneficial use (to avoid type II error or a negative false) yet avoid unnecessary concern where concentrations fall within the realm of natural groundwater conditions (to avoid type 1 error or a false positive. Significant technical discussions surround whether a site has observed a false-positive indicating contamination. A type I error (false-positive) occurs when a site (or well) is actually in compliance but the statistical test chosen for the trigger indicates that significant change has occurred. The probability of a type I error (or) is defined as the controllable significance level of the test (Sara and Gibbons, 2006). These error types and their probabilities are briefly discussed in Appendix A1.

The following decision approaches for determining triggers were proposed by Sara and Gibbons (2006):

- A regulatory mandated "hard" limit (or an Upper Cutoff Limit (UCL)) where no data should exceed the water quality standard with consideration given to sampling and laboratory error.
- The more flexible historic mean concentration at a well where the water-quality standard should not exceed this regulatory limit.
- The moving window approach where the last-year's mean concentration should not exceed the limit.
- Statistical limits where 95% of the population must be below the standard.

DLWC (1999) drafted guidelines for groundwater quality monitoring, however, these guidelines were identified to have deficiencies (e.g. Timms *et al.* 2005). Although these guidelines were for effluent irrigation sites, the principal of developing trigger levels can be used for other groundwater quality evaluations. The guidelines require at least ten rounds of baseline samples, even then, trigger levels suggested may be exceeded when concentrations measured are within the natural variability of the groundwater baseline conditions (Timms *et al*. 2005).

In 2007 WRL proposed an advanced statistical method combined with hydrogeological considerations for establishing the trigger levels at a site where groundwater quality was potentially impacted by irrigation of effluent. The following principles were applied:

1. Maximum acceptable values or the Upper Cutoff Limit (UCL) that represents the upper boundary of baseline water quality should be established for all groundwater quality indicators and should not be exceeded in any sample. If the UCL is higher than the target beneficial use indicator for any analyte, the value of the beneficial use should be adopted as the UCL.
2. Concentrations of parameters measured in groundwater quality samples should not be consistently increasing above the mean.

The number of consecutive samples that may be measured above the mean prior to triggering correction actions may be determined by the operators of the groundwater monitoring program based on acceptable statistical confidence (Anderson and Badenhop, 2007).

In 2008 WRL (Timms *et al.* 2008) modified the DLWC (1999) guidelines to develop the following interim groundwater quality trigger values:

1. All of the last four measurements were above the baseline maximum.
2. All of the last four measurements were above the baseline mean and increased in value from the previous value.
3. Concentration exceeds guideline values for the identified highest beneficial use.
4. All of the last four measurements show increasing groundwater salinity or changes in water type as plotted on a piper diagram.

These trigger values represent an attempt to ascertain whether or not significant trends are occurring within the data.

2.3.2 *Statistically Valid Techniques for Analysing Limited Amounts of Data*

Application of statistically robust methods is dependent on the availability of adequate data and should not replace a professional evaluation of potentially significant changes in groundwater status. The distinction between statistical significance and practical significance is important to consider. Statistical significance is a concept based on the weight of evidence that a hypothesis is valid. In some cases small, statistically significant changes may not have any practical significance (USEPA, 2006). An understanding of the groundwater system and factors that contribute to the variability of groundwater quality is essential to informing a professional judgement as to whether changes are potentially significant, whether or not statistical analysis tools are used.

An example of statistical analysis to provide reliable and valid outcomes (NDDH, 2009) is outlined below:

1. Applicability to actual distribution of the data
2. Individual well comparisons to background groundwater quality or a groundwater protection standard shall be done at a type I error (indication of contamination when it is not present, or false positive) level no less than 0.10 or, if the multiple comparisons procedure is used, the experiment-wise error rate shall be no less than 0.10 (see Appendix A1)
3. If a control chart (or Shewhart chart) is used, the type of chart and associated parameter values shall be protective of human health and the environment (see Appendix A1)
4. The level of confidence and percentage of the population contained in an interval shall be protective of human health and the environment
5. Account for seasonal and spatial variability and temporal correlation of the data.

<u>Confidence Levels</u>

The statistical performance standards provide a means to limit the possibility of making false conclusions from the monitoring data. The specified error level of 0.10 for individual well comparisons for probability of type I error (indication of contamination when it is not present, or false positive) essentially means that the analysis is predicting with 90 percent confidence that no significant increase in contaminant levels is evident. The corollary is that there is only a 10 percent chance that a type II error (failure to detect a significant increase in constituent concentration, or false negative) has occurred (NDDH,2009).

Where there is not enough baseline data available, alternative statistical methods need to be used to find the maximum acceptable values or Upper Cutoff Limit (UCL) for a target indicator. This should be established using an estimate of the prediction interval (PI) for the available baseline data (Appendix A1). The prediction interval is the upper boundary of the likely population of baseline groundwater quality, rather than the recorded maximum of the samples taken. This ensures that the UCL takes into account uncertainty intervals based upon limited sample sizes.

The mean value of a target indicator should be calculated from the upper Confidence Interval (CI) estimate of the mean thus reducing the uncertainty regarding the estimated mean of the target indicator (Anderson and Badenhop, 2007).

Tests of Trend

Trends in data could be observed as a gradual increase (usually modelled as a linear function) or a step function or even cyclical on a seasonal basis. Graphs of changes of time can enable a highly effective evaluation of data and provide an indication of whether or not statistical methods can be applied, and if so, which tests may be relevant.

A number of statistical methods can be applied to data sets to evaluate for trends and seasonality (Sara and Gibbons, 2006). The length of time recommended to obtain adequate long-term trends is 2 years of data (Doctor *et al.* 1986 in Sara and Gibbons, 2006); for seasonal trends, a much longer period data set may be necessary. Goodman (1987) in Sara and Gibbons (2006), using a modified Mann–Kendall test, found that at least 10 years of quarterly data were required for obtaining adequate power to detect seasonal trends (Sara and Gibbons, 2006). There should be a good scientific explanation and empirical evidence for the seasonality before corrections are made. Consistent seasonal trends of groundwater quality are not expected in the Namoi catchment, particularly in groundwater that is sampled from more than a few metres below the ground surface.

General upward or downward trends, if present, can be detected and the analyst can follow-up with a test for trend, such as the Mann-Kendall test (see Appendix A1). Mann-Kendall tests are non-parametric tests for the detection of trend in a time series. These tests are widely used in environmental science, because they are simple, robust and can cope with missing values and values below a detection limit (Hydrogeologic, Inc., 2005). With limited groundwater quality baseline data, there is a smaller chance of having normally distributed sample data, therefore nonparametric methods can provide much more reliable conclusions than parametric methods (parametric methods assume that data comes from a type of probability distribution and makes inferences about the parameters of the distribution).

3. CONNECTIVITY INDEX TO DEFINE MONITORING UNITS

As discussed in Report 1 (WRL Technical Report 2009/04), the main source of groundwater in the Upper and Lower Namoi Alluvium GWMA's is the Gunnedah subsystem (up to 110 m thick), which consists of coarser grained sands and less clay content than the overlaying Narrabri subsystem (up to 40 m thick). However, there are significant clays in the lower sand unit (Gunnedah subsystem) and significant sands in the upper clay rich unit (Narrabri subsystem).

In the past, presentation of monitoring results from this complex stratigraphy has been simplified by assuming a common depth boundary between the subsystems, above which is the upper aquifer and below which is the lower aquifer (e.g. Lavitt, 1999). The reality is that there are poorly defined boundaries throughout the alluvium; in some areas the whole alluvium may be connected, while in others, there may be very poor or essentially no connection between the upper and lower alluvium. For example, hydrograph analysis documented in the draft Lower Namoi Status Report 2004 (DNR, 2006) demonstrated that connectivity varies even in geographically close areas. Close to Narrabri, the connection is poor, yet the shallower aquifer shows some decline in head over time in response to the deeper aquifer (>60 m.b.g.). On the south side of the bedrock high north of Pian Creek and to the west of this site, groundwater levels are in a state of ongoing decline with the shallower aquifer being dewatered showing strong connectivity between the resources (DNR, 2006).

For this reason, a method to distinguish between the upper and lower monitoring unit of the alluvium has been determined based on the connectivity of the resources, such that results of monitoring can be presented for the upper and lower monitoring units.

The connectivity of aquifers can be seen by comparing hydrographs between pipes at different depths in the same bore when the aquifer is under stress. Where the aquifer is well connected, the difference in head level between two overlying pipes over a yearly stress period should be minimal. Using this premise, WRL in conjunction with the Connected Waters Initiative (CWI) (Bryce Kelly) completed an automated analysis of all of the monitoring bores in the Namoi catchment to determine the connectivity between overlying pipes. This analysis was completed for the stress year of 1986. Where the difference in head was below the determined threshold difference (3 m), the aquifer was termed 'connected', whereas below this threshold, the aquifer was termed 'poorly connected'.

It is recommended that further development of the connectivity method be completed in the future, however, an initial verification of the method was carried out for Zone 3 of the Upper Namoi (Appendix A2). Assumptions and limitations inherent in this method at this time are listed below:

- The upper pipe is assumed to be intersecting the upper monitoring unit
- Analysis was only completed where accurate data was collected for the analysis year which limited the number of bores that could be presented
- A poorly installed monitoring bore may create a connection through all the monitoring units
- The threshold difference determined as the cutoff between a 'connected' and 'poorly connected', while determined through sensitivity analysis, is yet to be thoroughly verified.

For WRL target bores, examination was made of hydrographs where the scripting process could not resolve the connectivity. Where there was only one pipe and the depth was less than 30 m below ground level, it was assumed that it was intersecting the upper monitoring unit. For one bore, the distinction was made using electrical conductivity (GW040822).

All figures following that present data in terms of "Upper Monitoring Unit" and "Lower Monitoring Unit" have separated the data into these units based on these method. Where there were several pipes of one bore in the one unit, the data was either averaged or the maximum taken, depending on what was most appropriate for the data type.

Table 2
Distribution of Monitored Bores in Upper and Lower Monitoring Units

Monitoring Unit	GMU	Zone	No. Pipes Monitored
Upper	(001) Lower Namoi Alluvial		26
	(004) Upper Namoi Alluvium	Zone 2	5
		Zone 3	15
		Zone 4	8
		Zone 5	5
		Zone 6	2
		Zone 8	4
		Zone 9	3
		Zone 12	2
	(005) Peel Valley Alluvium		4
Lower	(001) Lower Namoi Alluvial		4
	(004) Upper Namoi Alluvium	Zone 2	3
		Zone 3	4
		Zone 4	3
		Zone 5	1
		Zone 6	4
Deeper	(004) Upper Namoi Alluvium	Zone 4	1

4. GROUNDWATER MONITORING 2009

The following two groundwater monitoring programs were completed in 2009:

a) Groundwater sampling by growers - samples voluntarily collected by irrigators/growers in the Namoi catchment and sent to WRL for analysis

b) Groundwater sampling of DECCW monitoring bores - three sampling rounds of strategic monitoring bores by WRL staff.

The suite of parameters was focused on salinity as being the primary water quality issue in the Namoi catchment.

In addition to bores sampled for this project, groundwater samples are also currently being obtained for other specific projects in the Namoi catchment, including, but not limited to:

- Monitoring of groundwater salinity below the Cryon Plains by DECCW
- Research investigations in the Maules Creek area by UNSW Connected Waters Initiative
- Research investigations in the Cockburn Creek area by Cook *et al.* (2007)
- Coal and gas exploration and monitoring programs in various areas.

4.1 Groundwater Sampling by Growers

Growers and landholders in the Namoi catchment were encouraged to participate in monitoring by collecting a sample from a groundwater bore on their property. An information package regarding the program (see Appendix A3) was distributed to growers through the Namoi CMA, Cotton CRC, NSW Farmers and Namoi Water with sample bottle packs made available at collection points throughout the catchment.

Laboratory supplied bottles were used to collect groundwater for testing electrical conductivity (EC), pH, chloride, sodium, magnesium, calcium, potassium, sulfate and bicarbonate alkalinity. Participants were encouraged to use a water quality meter if available to measure pH, EC and temperature immediately, as groundwater flows from the bore. These results were used to calculate indicators of importance to irrigation usage (total dissolved salts, sodium adsorption ratio and hardness).

4.1.1 Sampling Method

Samples were collected in pre-treated bottles and analysed by the Australian Laboratory Services (ALS) for major ions and EC. pH was measured using a pH strip with 1 unit increments at the sampling time by the sampler (Grower). Running time for the pumps varied from 30 days to a few minutes before the samples were taken, therefore some samples would represent the groundwater conditions well, while others would fail to do so. Sample bottles were sent to the Water Research Laboratory via Australian Post, unrefrigerated and kept refrigerated from the time of receiving until analysed by ALS Laboratory Group.

4.1.2 Results

A total of 79 samples were received by the Water Research laboratory. Two of these samples were not accompanied by any information on the location and therefore couldn't be spatially analysed. Table 3 has a summary of grower samples locations accuracy.

Table 3
Growers Samples - Accuracy of Bore Locations

Accuracy of Bore Location	No of Samples
Exact (coordinates provided)	26
Good approximation (irrigated property address provided)	11
Approximation (only post code provided)	40
Unknown (no address provided)	2
Total	79

These samples cover a large area of the Namoi catchment including fractured rock (Figure 2), while the WRL monitoring project was designed specifically to sample alluvial aquifers. The distribution of samples throughout the Groundwater Management Areas (GWMA), along with electrical conductivity (EC) is summarised in Table 4, and shown pictorially in Figure 3. Most of the samples can be seen to be fresh water (< 1500 µS/cm). The maximum recorded EC (7590 µS/cm) is found in the Lower Namoi Alluvium between Wee Waa and Walgett, while many samples with brackish water were spread throughout the Upper Namoi Alluvium. While the samples are spread across a large area of the catchment, the coverage of these samples is sparse within each GWMA (i.e. only 1 sample in some zones). There is insufficient data to meaningfully define minimum, maximum, and average EC values for these zones.

Table 4
Growers Samples - EC Results

GWMA	Zone	No of Samples	EC (µS/cm)		
			Min	Max	Average
(063) GAB Alluvial		3	594	1420	1144
(601) Great Artesian Basin		5	64	954	488
(604) Gunnedah Basin		12	504	4200	1850
(814) Liverpool Ranges Basalt		2	889	2310	1599
(001) Lower Namoi Alluvium		18	252	7590	1176
(023) Miscellaneous Alluvium of Barwon Region		2	1130	1870	1500
(805) New England Fold Belt		7	798	2250	1131
(608) Oxley Basin		2	1140	1220	1180
(819) Peel Valley Fractured Rock		4	548	1880	1025
(004) Upper Namoi Alluvium	2	3	580	2560	1773
	3	3	452	758	574
	4	7	340	2230	798
	5	2	960	2470	1715
	6	2	853	2000	1426
	7	1	1270	1270	1270
	8	3	693	1240	947
	11	1	674	674	674
Total		**77**	**64**	**7590**	**1214**

A statistical summary of grower samples is shown in Table 5.

Table 5
Statistical Summary of Grower Samples Analysis

Statistical Summary	**Electrical conductivity**	**TDS**	**Sodium**	**Calcium**	**Potassium**	**Magnesium**	**Chloride**	**Sulfate**	**Bicarbonate**	**Bicarbonate as CaCO3**	**Carbonate**	**Alkalinity (Hydroxide) as CaCO3**	**Alkalinity (total) as CaCO3**	**Sodium Absorption Ratio**	**Hardness as CaCO3**	**Anions Total**	**Cations Total**	**Ionic Balance**
	uS/cm	**mg/L**										**µg/L**	**mg/L**	**units**	**mg/L**	**meq/L**		**%**
Number of Results	79	79	79	79	79	79	79	79	79	79	79	79	79	71	71	79	79	75
Number of Detects	79	79	79	76	68	73	79	75	79	79	10	0	79	71	71	79	79	74
Min Concentration	64	38	8	<1	<1	<1	4	<0.25	9.76	8	<1	<1000	8	0.7	21.5	0.53	0.51	<0.01
Max Concentration	7590	4883	1630	257	17	135	2060	859	1830	1500	127	<1000	1500	42	1052	77.2	77.1	5
Ave Concentration	1225	950	170	54	2.9	37	165	53	469	384	6.1	500	392	4.4	318	14	13	1.9
Med Concentration	954	722.32	96	43	2	27	64.2	18.6	419.68	344	0.5	500	344	2.3	265	10.3	9.92	1.68
Standard Deviation	1050	755	227	48	3.3	31	278	110	298	244	19	0	250	6.7	221	11	11	1.3
Guideline Exceedances (Detects Only)	21	53	24	0	0	0	17	2	0	0	0	0	0	0	45	0	0	0

According to this table, EC (μS/cm) exceeded at least one of the guidelines in 21 cases with a maximum value of 7590 μS/cm. These results all comply with the upper cut-off limit for cotton irrigation. Therefore water quality in general is very well suited to irrigation and livestock farming and 56 samples (out of 79) are drinkable according to Australian Drinking Water Guidelines (ADWG, 2004) with EC values under 1400 μS/cm. The distribution of the conversion factor between TDS and EC was studied in this group of samples. This ratio (TDS/EC) varied between 0.45 and 1.1 with an average value of 0.77, while in ANZECC guidelines (2000) the recommended conversion factor has been set to 0.67 for irrigation water. There is no specific factor that applies to most of the data but it can be said that 75% of the conversion factor values are between 0.6 and 0.8 for this group of samples.

Chloride concentrations of 17 samples exceeded at least one of the guidelines indicating a potential risk to growth, foliar injury, or increased cadmium intake in cotton and sunflower. The average concentration of chloride in these samples shows that it is mostly under the upper limit for drinking suitability.

Sulfate concentration exceedances can cause chronic acute health problems in livestock. Only 2 samples are flagged in regards to sulfate concentrations and the majority of the samples are under drinking water upper limit cut-off concentration.

TDS (total dissolved solids), is the sum of calcium, sodium, potassium, magnesium, chloride, sulfate, and bicarbonate. In 51 samples this value exceeded at least one of the guidelines. According to ADWG (2004) TDS guidelines, 47 of 79 samples are of fair drinking quality.

Sodium concentrations were detected over guidelines (drinking and irrigation) in 24 samples, only 4 of which exceeded the irrigation limits. The average sodium concentration remains suitable for drinking for these samples.

A statistical correlation investigation between each pair of six parameters including EC, TDS, Na^+, and Cl^-, sodium adsorption ratio (SAR), and hardness as $CaCO_3$ is shown in Table 5. The correlation analysis shows that EC and TDS have a strong positive correlation (r^2 = 0.97), while TDS and sodium have r^2 = 0.92 correlation. This positive correlation means that these parameters are strongly affected by each other, in other words an increase in TDS can indicate an increase of almost the same magnitude in sodium concentration.

Table 6
Correlation Analysis (r^2 value) for EC, TDS, Na^+, Cl^-, SAR, and Hardness as $CaCO_3$ for Growers Samples

	EC (µS/cm)	TDS(mg/l)	Sodium (mg/l)	Chloride(mg/l)	SAR
Electrical conductivity	1				
TDS	0.97	1			
Sodium	0.92	0.92	1		
Chloride	0.94	0.84	0.84	1	
SAR	0.78	0.80	0.94	0.71	1
Hardness	0.49	0.51	0.18	0.38	-0.08

Figure 4 shows the effect of irrigation water EC and SAR on soil stability. Water compositions that occur to the right of the equilibrium lines are considered satisfactory for use, provided the SAR is not so high that severe dispersion of the surface soil water will occur following rainfall. If a sample is located in the green zone, it can be concluded that it does not impose any risk to soil structure suitability as a result of irrigation. Samples located in the yellow zone need to be closely monitored for rising EC or SAR, and can impose a potential risk on soil structure suitability depending on the soil properties (such as porosity, grain size, etc) and rainfall (dilution of the irrigation water). Samples located in the red zone are more likely to degrade the soil structure and should only be used for irrigation with great caution (Department of Environment and Conservation (NSW), 2004).

SAR and EC values for the growers samples were plotted against each other in a logarithmic fashion and then super-imposed on the DEC (2004) plot. These samples are mostly in the "Stable Soil Structure" zone, in some samples soils structural suitability depends on soil properties and rainfall, while a few samples are likely to cause soil structural problems.

Sample results were distributed to participating growers in the form of a two page report providing comments on the suitability of groundwater for irrigation, livestock, and drinking purposes (see example in Appendix A4). As these results were treated confidentially, they are not linked to bore numbers and were not included in the groundwater quality database for the Namoi CMA and Cotton CRC (see Section 6.2.8).

4.2 Groundwater Sampling of Monitoring Bores

Three sampling rounds were completed by WRL in 2009 during January, March and July to examine whether significant groundwater quality variations occur between high stress periods (summer) and low stress periods (winter). Available resources for this project meant that each of the three sampling campaigns were to be undertaken in about 10 field days. DWE monitoring bores were targeted because these bores are specifically designed with relatively short intake screens and narrow casings for better definition of groundwater status, as discussed in Timms *et al.* (2009).

A semi-quantitative methodology was adopted to target monitoring bores. There was insufficient time to apply geostatistical techniques to optimise monitoring bores. Berhane & Tennakoon (2003) recommended that the density of this network should be highest in recharge areas, yet also include hot spot zones and vulnerable areas, whilst monitoring both shallow and deep aquifers. The targeted monitoring bore network includes representative monitoring bores in all of these suggested areas, though perhaps not with the recommended density. Some of the targeted monitoring sites chosen are the same as those suggested by Berhane & Tennakoon (2003).

Criteria for selecting representative bores for sampling included the following:

- Coverage of groundwater management zones
- Data availability from previous monitoring
- Proximity to major groundwater extraction
- Proximity to river recharge sources
- Groundwater quality changes identified
- Proximity to significant salt sources.

Additional bores were added to the targeted monitoring bores in time for the July sampling trip after further analysis of historical salinity data indicated that some additional bores were showing evidence of increasing salinity over time.

It was not possible to analyse hydrographs prior to monitoring bore selection due to time constraints. Target bore pipes in the Lower Namoi were able to be optimised where hydrograph plots were readily available (B Kelly, pers.com.). This involved targeting pipes to represent two different hydraulic zones (upper and lower) and eliminate pipes where water levels indicated that intakes were blocked.

The targeted monitoring bores are shown in Figure 5 along with irrigation areas, and surface water sites. The bores are listed in Appendix A5, along with the rationale behind choosing each site. The locations of surface water sites are also given in Appendix A5, along with details of bores that were visited and could not be sampled.

A summary of samples collected for field and laboratory analysis is provided in Table 7.

Table 7
Summary of Monitoring Bore Sampling by WRL

Month, 2009	**Field Chemistry Measurements**	**Major Ion Analyses**	**Number of Pipes**	**Number of Bore Sites**
January	60	60	60	49
March	66	17	66	39
July	63	44	63	50
Total	**189**	**121**	**189**	**138**
Target*	180 (60 × 3)	90 (30 × 3)	180 (60 × 3)	

4.2.1 Sampling Method

The following sampling methods were used by WRL personnel during three rounds of sampling in January, March, and July 2009:

- All deep bores were purged prior to sampling and water level measurements were recorded prior to and during purging.
- Shallow bores were sampled using a low flow method while continuous measurements ensured no change in the standing water level values.
- Field measurements were taken using specific water quality meters and a flow cell. These measurements included electrical conductivity (EC), dissolved oxygen (DO), acidity (pH), temperature (T), and redox (Eh).
- Readings of field parameters were recorded after stabilising.
- All water quality meters were calibrated at the beginning of each sampling day.
- A number of duplicates were taken and sent to the laboratory to ensure the analysis quality and the robustness of the results.
- All samples were kept refrigerated from the time of sampling to the time of analysis.
- Some comparison to check the coherence between the readings against laboratory result report (i.e. field measured EC vs. calculated TDS).

Standard WRL groundwater sampling procedures, compliant with Australian Standards are found in Appendix A6. These sampling procedures include purging of stagnant water and calibration of water quality meters and sondes.

Low flow sampling was adopted wherever possible to minimise the need to purge stagnant water and enable more samples to be collected in the available time. Low flow sampling was carried out by positioning the pump intake at the bore screen, ensuring no significant drawdown occurred during sampling and minimising pump rates to <1 L/min. Further details are provided in Appendix A6.

For the first sampling round, sampling pumps included the following:

- Air-driven Bennett sampling pump was used to sample bore intake screens to a depth of 80 m. This pump was suitable for use if the standing water level (SWL) was <25 m below casing, with extension tubes fitted to obtain water directly from the screen intake.
- 12V powered Monsoon pump. This pump was suitable for bore screens up to 25 m depth.

For the second and third sampling round, an additional sampling pump was obtained that enabled sampling of sites where the SWL and/or intake screen was up to 80 m below casing. This 240V electric Grundfos MP1 submersible pump was required at some sites where SWL were subject to significant drawdown.

Samples were provided to Australian Laboratory Services, which are NATA accredited for major ion analysis. Standard QA/QC procedures were adopted including blind field duplicates, chilling of samples and compliance with maximum holding times. Charge balance errors of <5% indicated acceptable standard of analysis.

4.2.2 Results

The complete results (water levels and water quality) from the three WRL monitoring rounds are shown in Appendix A7, with official laboratory results in Appendix A8.

4.2.2.1 Water Levels

Snapshots of the standing water levels recorded over the 3 sampling events are shown for the upper monitoring unit in Figures 6-8 and for the lower monitoring unit in Figures 9-11. A complete set of these maps at higher resolution zoomed into the Upper Namoi (1:1,000,000), Upper Namoi Zone 3 (1:250,000) and Lower Namoi (1:1,000,000) are given in Appendix A7. The water levels in metres AHD are shown for comparison for Round 1 in Figures 12 and 13. It is important to note that some of the apparent differences between the maps for each sampling round are actually due to additional bores being sampled.

The greatest depth to groundwater (>40 m) in the upper monitoring unit is to the north-west of Wee Waa in the Cryon region (Figure 6). All of the monitoring bores around Wee Waa display depths to groundwater greater than 20 m, other than those very close to the Namoi River, upstream of Wee Waa. In Upper Namoi, the depth to groundwater is greatest in Zone 3, near Curlewis and in Zone 12. In comparison with the groundwater elevations shown in Figure 12, it can be seen that the main anomaly in the generally trend of decreasing groundwater elevations from the Upper Namoi to the Lower Namoi is in Zone 3 near Curlewis. Figures 7 and 8 do not show any apparent change between sampling rounds at this resolution.

Data from the lower monitoring unit is more sparse. In the Lower Namoi, depths to groundwater are greater than 20 m even along the Namoi River upstream of Wee Waa (Figure 9). In the Upper Namoi, depths to groundwater are greatest along the Cox's Creek (Zone 2) and in Zone 3. While there is little apparent change between sampling rounds, some recovery is evident in July around Boggabri (Figure 11). The groundwater elevations shown in Figure 13 do not show any real anomalies in the expected trend from the Upper Namoi to Lower Namoi.

4.2.2.2 Water Quality

The range of salinity of the 2009 samples across the GWMA's is shown in Table 8. It can be seen that while the Peel Valley Alluvium has a very small range of electrical conductivity (EC) in the bores sampled, the electrical conductivity of groundwater in the Upper and Lower Namoi is very varied. From the minimum EC measured in each Zone, it can be seen that high quality water exists in every zone, yet maximum EC shows there is also marginal water in most of the zones. The highest electrical conductivity measured (26 500 μS/cm) was in the Lower Namoi Alluvium, whilst in the Upper Namoi Alluvium, the highest EC measured (19 000 μS/cm) was in Zone 3.

Table 8
WRL Monitoring EC Results Summary

GWMA	Zone	No of Samples	EC(µS/cm) Min	Max	Average
(001) Lower Namoi Alluvium		63	272	26500	2432
(004) Upper Namoi Alluvium	Zone 2	17	879	5895	3129
	Zone 3	27	736	19000	3604
	Zone 4	27	283	1850	731
	Zone 5	18	442	769	593
	Zone 6	11	818	9694	3419
	Zone 8	8	946	1117	1056
	Zone 9	7	690	1380	1012
	Zone 12	4	737	1512	1117
(005) Peel Valley Alluvium		12	363	646	483

The salinity measured for each of the monitoring rounds for the Upper monitoring unit is shown in Figures 14-16. The scale of these maps is roughly divided into categories of beneficial uses. The best quality water is found along the river. Even in the Upper monitoring unit there is a large range of EC measured. Poorer quality water is found to the far west of the Lower Namoi Alluvium, but also in hotspots throughout the catchment around Curlewis (Zone 3), Zone 6, Boggabri (Zone 4) and Narrabri (Zone 5). It is important to note that some of the apparent differences between the maps for each sampling round are actually due to different bores being sampled. However, it can be seen that there does seem to be some reduction in salinity around Narrabri between monitoring rounds 1 & 3, which may be the effect of recharge along the river.

The salinity measured for each of the monitoring rounds for the Lower monitoring unit is shown in Figures 17-19. While there is less data, overall the EC measured is lower than in the Upper monitoring unit. At the same time, it can be seen that the areas with higher salinity correspond to those areas with higher salinity in the Upper monitoring unit (i.e. around Curlewis (Zone 3), Zone 6, Boggabri (Zone 4).

A comparison of the measurements of surface water and groundwater salinity for the WRL monitoring rounds is shown in Figure 20. It should be noted firstly that there are only two data points to compare for Surface sites # 01 – 04 and therefore no meaningful conclusions can be made. However, it is worth making a few simple observations regarding the data. Groundwater is slightly more saline (within 300 µS/cm) than surface water at sites #01, #04 and #05. While there is not enough data to comment on definitively on trends, it does appear that at these sites, there is a good correlation in trends between surface and groundwater. Surface water is very slightly more saline than groundwater at site #04, but again there does seem to be some correlation between surface water and groundwater salinity. At surface water sites #06 and #07, neither surface water or groundwater are consistently higher than the other and the results for the two sites appear quite similar. Surface water and groundwater are most saline at sites #06 and #07 along the Mooki River in Zone 3.

It is interesting that between the two sites along the Peel River there is an inversion in the relationship. At site #05, groundwater is more saline than surface water, while at site #04 downstream, surface water is very slightly more saline than groundwater.

There would be value in continuing to monitor these surface and ground water sites concurrently so that long term observations could be made regarding the relationship between groundwater and surface water at these sites.

A statistical summary of WRL samples analysed by ALS is shown in Table 9. This table shows statistical characteristics of WRL samples results including: number of results, number of detects, minimum concentration, maximum concentration, average concentration, median concentration, standard deviation, number of guideline exceedances.

Table 9
Statistical Summary of WRL Samples Analysis

Statistical Summary	Electrical conductivity	TDS	Sodium	Calcium	Potassium	Magnesium	Chloride	Sulfate	Bicarbonate	Carbonate	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Sodium Absorption Ratio	Hardness as CaCO3	Anions Total	Cations Total	Ionic Balance
	uS/cm	mg/L									µg/L	mg/L	units	mg/L	meq/L		%
Number of Results	198	110	111	111	104	110	111	111	111	111	111	111	108	108	111	111	110
Number of Detects	198	110	108	107	104	110	111	111	2	2	0	111	108	108	111	111	110
Min Concentration	272	206	14	2	1	1	6	0	120	8	<1000	120	1	17	0.58	0.62	<0.01
Max Concentration	28500	21207	6570	6768	16	7071	10400	5490	1650	31	<1000	1650	49	5373	356	373	5
Ave Concentration	2320	2430	672	172	3	160	809	392	362	20	500	363	10	584	31	32	2
Med Concentration	931	793	137	44	2	29	100	40	315	20	500	315	5	243	10	10	2
Standard Deviation	3931	4095	1308	682	3	693	1801	1034	221	16	0	222	11	997	56	59	1
Guideline Exceedances (Detects Only)	59	70	31	0	0	0	27	18	0	0	0	0	0	55	0	0	0

According to this table, EC µS/cm exceeded at least one of the guidelines in 59 cases (n=198) with a maximum value of 28500 µS/cm and a minimum of 272 µS/cm. The average EC for this data group is 2370 µS/cm which indicates a poorer quality compared to the growers samples (with an average EC of 1225 µS/cm). On average water quality is suitable for livestock and irrigation other than early season cotton, which requires water with EC <1500 µS/cm.

TDS values exceeded at least one of the guidelines in 70 samples (n=110). Of these exceedances, 49 cases are potentially risky for irrigation or livestock, with only 6 samples exceeding 13000 µS/cm that is the UCL for sheep.

Chloride concentrations of 27 samples (n=111) exceeded at least one of the guidelines indicating a potential risk to growth, foliar injury, or increased cadmium intake in cotton and sunflower. The average concentration of chloride in this data group (809 mg/l) is higher than the UCL for potential risk of increased cadmium intake in cotton and sunflower.

Sodium concentrations were detected over guidelines (drinking and irrigation) in 31 samples with an average concentration of 672 mg/l. This value is greater than both the limit for suitable drinking water(180 mg/l) and the limit for cotton irrigation (600 mg/l).

Sulfate concentrations exceeded the guidelines in 18 samples (n=111) indicating the possibility of chronic acute health problems in livestock. Out of 18 flagged concentrations, 8 samples are over 2000 mg/l, 3 are over 1000 mg/l (risk to the livestock), and the rest of the exceedances are above the drinking water guidelines.

A statistical correlation investigation between each pair of six parameters including EC, TDS, Na^+, Cl^-, SAR, and Hardness as $CaCO_3$ is shown in Table 10. The correlation analysis shows that EC and TDS have a positive correlation (r^2 = 0.95), while TDS and Sodium have a very strong correlation (r^2 = 0.99). This positive correlation means that these parameters are strongly affected by each other, in other words an increase in TDS can indicate an increase of almost the same magnitude in Sodium concentration. As shown in Table 10, EC has the same correlation with Sodium as it has with TDS which supports the 99% correlation between Sodium and TDS. This shows that EC is a good indicator of total salts for groundwater in the Namoi catchment.

Table 10
Correlation Analysis for EC, TDS, Na^+, Cl^-, SAR, and Hardness as $CaCO_3$ for WRL Samples

	EC (µS/cm)	TDS(mg/l)	Sodium (mg/l)	Chloride(mg/l)	SAR
Electrical conductivity	1				
TDS	0.95	1			
Sodium	0.95	0.99	1		
Chloride	0.91	0.95	0.97	1	
SAR	0.70	0.71	0.73	0.66	1
Hardness	0.92	0.97	0.95	0.93	0.56

The most suitable factor to convert indicative values to TDS was assessed to provide a recommendation for future studies. This statistical examination shows an average of 0.76 as the conversion factor with a maximum of 1.24 and a minimum of 0.53. The standard deviation of this group is 0.10 which clearly show a strong tendency to the centre (the average value) for each individual data in this group. This value is very close to the conversion factor calculated from the growers samples (0.77) and it is higher than the value of 0.67 suggested by ANZECC (2000).

SAR and EC values for the WRL monitoring samples were plotted to determine suitability for irrigation with respect to soil structure (Figure 21). These samples are mostly in the red zone, indicating that most of the water from monitoring bores could result in soil degradation if used for irrigation.

4.2.2.3 Water Quality Variation between January and July

There was some variation in groundwater quality observed at monitoring bores between January and July, 2009. Groundwater EC changes between January and July are summarised in Table 11. At most sites, groundwater EC variability was <10% (i.e. no significant change). Groundwater EC decreased for 11.4% of data, and increased for 6.2% of data. Table 12 shows the EC measured for each monitoring round for those bores that that showed significant change between January and July. This demonstrates that EC in January and March were generally similar, but EC in July could be either lower or higher than at other times in the year. Most EC changes were observed in the relatively shallow aquifer (i.e. Pipe 1), while groundwater EC was relatively stable in deeper aquifers.

These findings indicate that if possible, sampling for groundwater quality should be undertaken at a similar time each year. However, if that best practice is not possible, groundwater quality results for most sites, except some shallow sites, can be compared regardless when sampling occurred.

Detailed work at the Pullaming site in Zone 3 (Timms and Acworth, 2002) indicated that groundwater quality was most stable during the winter months when groundwater was not extracted for irrigation. However, this evaluation indicates that sampling could also be undertaken during summer when irrigation pumping is active (i.e. January-March). Although groundwater quality at the start of the irrigation season (around October-November) was not determined in these studies, it is clear that sampling at a similar time each year would be best practice for obtaining representative samples.

Table 11
Summary of Groundwater EC Changes in Monitoring Bores
(January to July, 2009)

	GW sites	Pipes	Data points	%
Total	43	83	193	
Increased EC	5	5	12	6.2
Decreased EC	6	8	22	11.4
No change	32	70	159	82.4

Table 12
Groundwater Monitoring Bores with Significant EC Variation
(January to July, 2009)

EC Trend	LocCode	Pipe	EC (uS/cm)	Monitoring time	% Change
Increase	GW025299	1	2963	March	
			4190	July	41.0
	GW030000	1	925	Jan	
			940	March	1.6
			1047	July	11.4
	GW030344	3	564	Jan	
			603	Feb	6.9
			669	July	10.9
	GW036314	1	12320	Jan	
			26500	July	115.2
	GW036541	1	10170	Jan	
			14910	July	46.6
	GW030061	1	1362	July	11.1
			1532	March	3.3
			1584	Jan	
Decrease	GW030184	1	953	July	12.2
			1086	March	2.8
			1117	Jan	
		2	946	July	10.7
			1060	March	4.1
			1105	Jan	
	GW036020	2	775	July	5.1
			817	March	18.6
			1004	Jan	
	GW036094	1	469	July	10.7
			525	March	1.9
			535	Jan	
	GW036140	1	433	July	18.5
			531	March	
	GW040822	1	7860	July	15.5
			9307	March	3.9
			9694	Jan	
		4	1417	July	10.6
			1585	March	2.3
			1622	Jan	

4.2.2.4 *Water Quality Variation with Pumping Drawdown*

The response of water quality to a pumping season was investigated by comparing the change in water levels and salinity over the WRL monitoring period. All of the hydrographs were compared with the salinity data and those showing some evidence of impact over the pumping season are shown in Figures 22 – 26. From closer examination of historical water level data, the maximum drawdown due to pumping in many bores occurs in early January, and therefore may have occurred prior to the first WRL sampling event. Where this is true, water levels are expected to show only recovery.

In the Lower Namoi (Figure 22), the most evidence of pumping impact can be seen in the water level recovery in GW025299 after the March sampling period. Salinity also increases in this bore over this period. While neither GW036314 or GW036541 show much variation in water level (perhaps indicating rapid recovery in GW036314 after the pumping season, which historically is impacted by pumping), there are large increases in salinity in Pipe 1 of both bores, with some decline after March. GW036541 seems to be far removed from irrigation areas (Figure 5) and this increase may therefore be unrelated to pumping. These pipes are screened at 29.5 m and 34.5 m respectively.

In the Upper Namoi, Zone 2 (Figure 23), there is evidence of water level recovery in the lower pipes of bores GW036515, GW036600 and GW036602 from March to July, with GW036600 and GW036602 showing recovery over the whole period. There also seems to be a corresponding decrease in salinity in these pipes after the March sampling period, with GW036602 decreasing in salinity over the whole period. The two sites GW036600 and GW036602 are close together spatially, south of Boggabri (see Figure 4), with the recovery in the lower pipes following the same trend.

In the Upper Namoi, Zone 3, (Figure 24), water level recovery can be seen in the lower pipes of GW036210 from January onwards. The SWL in the upper pipe of GW036166 (located north-west of Curlewis, on the western side of the Namoi) is distinctly different to that in the other bores, with water level showing recovery up until March and then declining. This period of recovery corresponds with increasing salinity, which then decreases as water level drops. While water level rises in both pipes of GW036210, EC decreases then rises in Pipe 1, but increases and then decreases in Pipe 3. In GW030000, water level decreases slightly throughout the pumping season, while salinity increases slightly. This site is very close to the river as discussed in Section 4.2.2.2 (Figure 20) and maybe influenced by surface water interactions.

In the Upper Namoi, Zone 4 (Figure 24), water level recovery is seen in all of the pipes shown. While salinity remains reasonably constant throughout this period in the upper pipes, there is a slight increase throughout the period in the lower pipe of GW030344, and increase prior to March in Pipe 3 of GW036238, which then decreases again.

In Zone 5 of the Upper Namoi (Figure 25), there are minor increases in salinity up until March and minor decreases after this time in all pipes shown. Corresponding water levels behave oppositely in the two bores shown. In GW030231 (located very close to the Namoi River), there is very minor drawdown prior to March, followed by recovery. In GW036094 (located further west from the river), the water level recovers over the whole monitoring period, with the steepest period of rise prior to March.

In Zone 8 of the Upper Namoi (Figure 25), water level steadily increases over the monitoring period while salinity decreases over the period.

Bores in the Peel Valley Alluvium (Figure 26) appear to have fairly constant water levels and salinities. All of these bores are located very close to the Peel River and surface water sites.

In summary, this analysis shows that the relationship between water quality responses and the pumping season is very complex. Some bores seem to show some evidence of salinity increasing while water levels decrease, while in others the reverse occurs. Further data at regular intervals over another pumping season would help to define these potential trends further.

4.3 Comparison of Groundwater Quality from Growers and Monitoring Bores

A comparison between the grower samples and the WRL monitoring samples shows a general agreement for most of the water quality and physical characteristics. Groundwater salinity results for grower bores and monitoring bores were similar (as discussed in Sections 4.1.2 and 4.2.2), except in specific parts of the catchment.

A specific comparison between EC values in the grower samples and the WRL monitoring samples showed significant differences at some sites in Zone 3.

Table 13 shows a list of adjacent samples from growers in comparison with WRL monitoring samples along with location and EC values. In most of the other sites these values were similar. Lack of information on grower samples (bore location, sample depth, etc) means that it is not possible to compare results in many areas with significant gaps. The relative differences between groundwater salinity ranged between -24% to +70%. This comparison indicates that groundwater salinity at a similar depth can vary significantly over a distance of kilometres within each Zone.

Table 13
EC Comparison Between Adjacent Grower and Monitoring Samples

Work NO	Opening Depth (m bg)	EC (µS/cm)	Closest Grower Sample *	Dist. (km)	Opening depth (m bg)	EC (µS/cm)	EC difference	
							(µS/cm)	%
GW036190	30.5-33.5	2541	G66	3.2	21-41	758	1783	70
GW036210	17.7-18.6	548	G32	11.9	17-22	513	35	-6
	73.8-77.4	1576						
GW036166	45.7-48.7	550	G6	5.6	?	452	130	-24
	77.4-80.4	345						
	95.7-98.7	826						

* The location of the grower sample has been estimated from information provided by the grower, but is not publically reported.
# Approximate distance between monitoring bore and sample bore

Other adjacent bores were monitored by WRL in Zone 3 and a summary of their EC values can be seen in Table 14.

Table 14
Groundwater Salinity at Monitoring Bores in Zone 3

Work NO	Opening Slot	EC(µS/cm)
GW036200	27.4-31.5	-
	42.7-45.7	1308
	85.3-88.4	1413
GW036202	48.8-51.8	2661
GW030000	10.7-21.4	1047
GW030430	16.7-19.8	-
	36.5-39.6	877
	53.3-56.3	-
	72.5-79.2	782

5. RISKS TO GROUNDWATER IN THE NAMOI CATCHMENT

Catchment management target MTW2 (see Section 2.1) specifies the need to “identify areas where groundwater is at risk from contamination” (Namoi CMA, 2007). This section aims to identify areas of risk in terms of long-term depletion of groundwater resources as measured by level and quality.

5.1 Beneficial Uses

As discussed in Section 2.2, it is the policy of the NSW Government to encourage the ecologically sustainable management of the State’s groundwater resources, so as to maintain the full range of beneficial uses of these resources (The NSW Groundwater Quality Protection Policy, 1998). The catchment management target MTW2 (Namoi CMA, 2007) specifies the need to prevent salinisation of productive aquifers and specifies target values in terms of electrical conductivity (EC). Investigating salinity (EC) changes with time at key sites can help to illustrate the potential risk to groundwater use in the Namoi catchment.

The main classes of beneficial uses of groundwater are shown in Figures 27-29, as quantified using average EC for the period 2000-2005, across the catchment in the upper, lower and deeper monitoring units of the Namoi alluvium. This time interval was used to provide a reference for the Catchment Management Targets which require an improvement or no change from 2006 (see Section 2.1). The detailed beneficial uses have been grouped together into the three main categories of Drinking, Irrigation and Poultry, and Livestock for ease of viewing. It is important to note the range of applicable values for the beneficial uses shown in Table 15 (reproduced from Table 1), as not all water within the category may be suitable for all uses eg. groundwater with EC of 7000 µS/cm will be classed as ‘Irrigation and Poultry’, however while it is suitable for cotton and barley irrigation, it will not be suitable for sunflower or wheat irrigation.

Table 15
Beneficial Use Range

Map Beneficial Use Category	Average EC (µS/cm)	EC (µS/cm)	Limits of Suitability with Range
Drinking	0 – 1,500	<120	Excellent drinking water quality.
		120-750	Good drinking water quality.
		750-1200	Fair drinking water quality.
		1200-1490	Poor drinking water quality.
		>1490	Unacceptable drinking water
		1500	If used on early season cotton, the final yields could be diminished.
Irrigation and Poultry	1,500 – 8,000	5500	Unsuitable for Sunflower irrigation.
		6000	Unsuitable for Wheat irrigation.
		7700	Unsuitable for Cotton irrigation.
		8000	Unsuitable for Barley irrigation.
		5970	Loss of production and a decline in poultry condition and health.
Livestock	8,000 – 20,000	10450	Loss of production and a decline in dairy cattle and horses condition and health.
		11940	Loss of production and a decline in pigs condition and health.
		14920	Loss of production and a decline in beef cattle condition and health.
		19400	Loss of production and a decline in sheep condition and health.

Figure 27-29 shows that the majority of groundwater with data available is suitable for drinking water purposes. In the upper monitoring unit (Figure 27), water not suitable for drinking water (i.e. suitable for irrigation and livestock) is found to the west of and around the outskirts (i.e. further away from the Namoi River) of the Lower Namoi Alluvium; and in Zone 3 and Zone 6 of the Upper Namoi Alluvium. This pattern is reflected in the other two monitoring units shown in Figures 28 and 29. These maps demonstrate that for the majority of the catchment, water must not be degraded below the beneficial use of drinking water.

5.2 Risk Factors

Risk factors for groundwater in the Namoi catchment include high background salinity, proximity to salt sources, rate of groundwater extraction, irrigation intensity, soil type and distance from recharge sources. These factors are particularly important for groundwater salinity, while groundwater levels are determined mainly by groundwater extraction and recharge.

Irrigation areas are shown in Figure 1 and are concentrated around the Namoi River, particularly around Wee Waa. Groundwater usage for the Lower Namoi is given in Figure 30 and shows concentrated pumping around the Wee Waa region, with limited use to the west of Burren Junction.

High soil salinity increases the risk of groundwater salinisation, as salts can be mobilised through irrigation deep drainage and recharge events. The salt store in the top 2-3 m of soil in the Namoi catchment as a relative value is given in Figure 31. This map shows that the salt store throughout most of the Upper Namoi and Lower Namoi Alluvium is either moderate or high. Most of the Lower Namoi west of Pilliga and north of Wee Waa has high salt stores, which is reflected in the groundwater salinity in these areas. There are also high salt stores in Zone 3 near Curlewis, an irrigation area (Figure 1) and one of the areas shown to have lower beneficial uses than drinking water (see previous section). High salt stores are also found along Cox's Creek, which currently has drinking water standard groundwater (see previous section), but should be well monitored to prevent problems in the future.

Evidence of increasing groundwater salinity in Zone 3 between the 1970's and 1990's was presented by Lavitt (1999), whose findings are confirmed and expanded by this study. An increase by a factor of up to 4.7 was observed for monitoring bores intakes >30 m depth. Ratios of simple temporal (decade) weighted means TDS, specifically TDS(1990's)/TDS(1970's) were compared. Despite a slight overall increase in TDS (Figure 32), significant increases (up to 400%) were noted for samples taken from the Pliocene clays. The increased groundwater salinity was attributed to intrusion of saline porewater from surrounding clay aquitards.

In the Upper Namoi, recharge is primarily from rainfall, flood events and irrigation deep drainage and therefore spread widely over the catchment and subject to many unknowns (Timms *et al.* 2009). More detailed study by Lavitt (1999) showed that the majority of recharge in the Mooki River Catchment (Zone 3 and Zone 8) occurs in the upper catchment in the footslopes of the Melville Ranges. In the Lower Namoi, stream loss and occasional flood events are very important for recharge, while the majority of recharge has been found to occur between Myall Vale (west of Narrabri) and Wee Waa (Timms *et al.* 2009). In general, as distance from recharge sources increases, so does the risk of major drawdown and salinisation. However, where the major recharge source is irrigation deep drainage, salinisation may occur as a result of recharge, especially in those areas with high salt stores (Figure 31).

5.3 Risks Areas in the Namoi Catchment

This section outlines risk areas in the Namoi catchment identified through the analysis of historical water quality and water level data.

5.3.1 Water Quality

An analysis was completed on the historical water quality data available to compare the average EC from 1980-1999 to the average EC from 2000-2009, as a way of identifying possible trends in the data. The results are shown in Figures 33-36.

In the upper monitoring unit, most of the available data is centred around Zone 3 of the Upper Namoi. Figure 34 (focussed on the Upper Namoi) demonstrates increases in salinity in the Cox's Creek catchment (1 data point only) and in Zone 3 of the Upper Namoi. Both these areas were shown to have high salt stores (Figure 31). The largest increases occur east of the Namoi River in Zone 3 (average EC from 2000-2009 is 123% greater in GW036166 than the average from 1980-1999), however, these are intermingled with bores showing no real increase. In between Curlewis and the Namoi River, all bores showed some increase over this period (11-25%). It is certainly clear that this area is at major risk of salinisation.

Less data is available for the upper monitoring unit of the Lower Namoi (Figure 35), which in general seems to be fairly stable with respect to salinity (where data is available). There are a few points showing some increase in salinity to the south-east of Wee Waa towards the edge of the alluvium, and to the west of Burren Junction, towards Pian Creek.

There are not as many data points available in the lower monitoring unit (Figure 36), but the data available again shows a large area of risk around Zone 3 of the Upper Namoi. Those areas of Zone 3 showing particular increases in salinity are repeated in the lower monitoring unit, with the very large increases shown in between Curlewis and the Namoi River, and west of the Namoi River (GW036166).

An analysis was completed to see if there had been any change in beneficial use between 2000-2005 (as shown in Section 5.1) and 2006-2009. Only 27 bores of the 1268 monitoring bores across the catchment had sufficient data to analyse the beneficial use for both time periods. Table 16 shows the five bores (seven pipes) with changed beneficial use category, only one of which has lowered in quality. It is important, however, to note the resolution of the beneficial use categories (as described in Section 5.1). It still may be that while the water has remained within the broad beneficial use category of "Irrigation and poultry", that it is no longer suitable for sunflower and wheat irrigation or poultry watering, and is only suitable for cotton and barley irrigation.

Table 16
Change of Beneficial Use in the Namoi Catchment

LocCode	Monitoring Unit	Beneficial Use-2005	Beneficial Use-2009
GW030061	Lower	Irrigation and Poultry	Drinking
GW036166	Lower	Livestock	Irrigation and Poultry
	Upper	Livestock	Irrigation and Poultry
GW036190	**Upper**	**Drinking**	**Irrigation and Poultry**
GW036200	Upper	Irrigation and Poultry	Drinking
GW040822	Lower	Livestock	Irrigation and Poultry
	Upper	Livestock	Irrigation and Poultry

5.3.2 Water Levels

5.3.2.1 Hydrographs

Bores that are representative of groundwater conditions in each zone are shown in Figure 37. Hydrographs from these bores were given in the Upper Namoi Status Report 2004 (DIPNR, 2006) and Lower Namoi Status Report (Smithson, 2009) and have been reproduced for this report (Figures 38-50) with updated water level information. A summary of the outcomes from the hydrograph analysis are given in Table 16.

In Zone 1 of the Upper Namoi Alluvium (Borambil Creek, Willow Tree to the Quirindi-Pine Ridge Road), bores GW030029, GW030024 and GW030184 (Figure 38) can be seen to have all pipes highly connected. Water levels in these bores can be seen to fluctuate seasonally with the pumping cycles and have been shown to be strongly influenced by climate (DIPNR, 2006). Recent groundwater levels in these bores appears to be at or below the lowest recorded historically.

In Zone 2 of the Upper Namoi Alluvium (Cox's Creek, Mullaley to Boggabri), there is no clear correlation with rainfall (DIPNR, 2006). A detailed analysis of hydrographs and 3D connectivity was recently presented by Kelly (2009). In summary, it was found that groundwater levels in the semi-confined aquifers have declined by over 10 m over the past 20 years, but that groundwater levels have risen in 14 of the 33 locations. Most of the locations where groundwater levels are rising are in the unconfined aquifer, where rise may be a consequence of deep drainage.

Hydrographs from representative bores (Figure 39) show poor connection between upper pipe and lower pipes of each bore, other than for GW036508. Recovered levels in GW036508 display a continued decline in the recovered head readings. The hydrograph for GW036515 shows the reversal of hydraulic gradients between the upper and lower monitoring units after development in 1993, and ongoing decline in recovered water level heads which is at similar levels to 1997-1998. Record drawdown was recorded in the lower monitoring unit in 2007 and is greater in this bore than for the other representative bores in this zone, and a steady decline is seen in the upper monitoring unit, indicating that there may be some downwards leakage occurring. Similar responses in the upper pipes of bores GW036546 and GW036600 also indicate leakage from upper monitoring units, increasing the potential for aquifer compaction.

Recovered levels in bores GW036499 and GW036546 have improved a little since the worst recoveries recorded in 2004, though drawdowns continue to be of a similar magnitude. In contrast, recovered water levels in GW036600 and GW036478 are in continued decline. Record drawdowns were evident in these bores in 2006 and 2007 respectively.

Hydrographs for representative bores in Zone 3 of the Upper Namoi Alluvium (Mooki Valley - Breeza to Gunnedah) are shown in Figure 40. These hydrographs show varied connectivity between upper and lower pipes. All pipes in the lower monitoring unit show declining trends. Current recovery levels in the lower monitoring units of GW036152 and GW036190 are the worst on record, while recoveries in GW036097, GW036189 and GW036215 were worst around 2002 - 2003, but have improved very little since then. Certainly, since 2002-2003, there is a noticeable stepdown in recovery in all of the bores. Pipe 1 of GW036189 indicates there is dewatering occurring. There is a risk of compaction and loss of storage throughout the zone.

Hydrographs for representative bores in Zone 4 of the Upper Namoi Alluvium (Namoi Valley - Carroll Gap to Boggabri) are shown in Figure 41. Decline of recovered water levels is evident in all bores. GW030306 and GW030344 display the most evidence of pumping impacts with large seasonal drawdowns and increasing hydrograph separation between pipes over time, which may increase the potential for downward leakage. Water level recovery in these bores was the lowest recorded during 2006 and 2007 respectively. Recovered water levels during 2007 were also the lowest recorded for GW021093, GW036485, GW036513 and GW036007. Steps down in water level recovery are evident in most of these hydrographs for the major droughts of the early 1980's, mid 1990's and 2002/2003; no complete recovery to pre-drought levels were made after these steps.

Hydrographs for representative bores for Zone 5 of the Upper Namoi Alluvium (Namoi Valley - Boggabri to Narrabri) and Zone 11 (Maules Creek) are shown in Figures 42 and 43. Pumping impacts in Zone 5 are seen most clearly with seasonal drawdowns in bores GW036016, GW036005 and GW030233. GW030478, located in the downstream end of Zone 5 shows less seasonal pumping impact, but can also seen to be in a slight decline over time. There is some evidence of decline in these bores with recent recovered water levels the lowest on record. Pipe 1 in GW036005 became dewatered in 2007, and there is an upward hydraulic gradient in this location when water levels are recovered. Bores GW030129 and GW030132 are located close to Maules Creek in Zone 11, while GW030237 is located further from the creek in Zone 11, however all of the bores have maintained fairly stable water levels over time. Due to the similar patterns of extraction and recovery in Bore GW030233 (Zone 5) and GW030235 (Zone 11), DIPNR (2006) suggested that there was evidence that pumping in Zone 5 was impacting on Zone 11.

Representative hydrographs for bores in Zone 6 of the Upper Namoi Alluvium (Mooki Valley - tributaries of the Liverpool Range) and Zone 10 (Warrah Creek) are shown in Figure 44. Pumping impacts can be seen in GW030147 (in the north-west of Zone 6), with recovery levels depressed since 2002, while groundwater fluctuates with river levels in GW030141 (located on the Mooki River) and appears relatively stable over time. GW030176 (east of the Mooki River) is not showing climatic or extraction impacts, however, the upwards hydraulic gradient between the two pipes has reduced over time. GW030181 represents the seasonal fluctuations of the groundwater (DIPNR, 2006). GW030060 is the most impacted by pumping of the representative monitoring bores, with large seasonal drawdowns. The lowest recovered heads were seen in the mid 1990's and 2003; since this time recovered heads have been increasing. GW030059 is the only hydrograph shown for Zone 10 and is stable over time.

Representative hydrographs for bores in Zone 7 of the Upper Namoi Alluvium (Yarraman Creek) are found in Figure 45, however only one bore has data prior to 2001. Recovery has been improving in GW093101 and GW965576 since the lowest drawdown in 2003. Recovery in bore GW093103 was slower after 2003 than the recovery in the previous two bores, however, the bore has recovered to 2001 levels. This bore shows significant seasonal drawdown. Bore 036099 is the only one in Zone 7 with a long historical data set and is in the downstream end of the zone. Water levels are reasonably well correlated with rainfall (DIPNR, 2006). Hydrograph separation between the pipes was evident between 2001-2006, with Pipe 2 in the lower monitoring unit showing the impact of the extraction during this dry period. The hydraulic gradient between these pipes has reversed in periods of increased extraction, however, the bore has been recovering slowly since the record drawdown in 2003, and is close to 2001 recovery levels again, though there does seem to be some decline in recovery since the late 1990's. Bores GW093105 and GW093106 even further downstream than GW036099 are located close to the boundary of Zone 8. While water levels in GW093105 have been relatively stable, there has been some decline in recovery in GW093106 in response to pumping.

Representative hydrographs for Zone 8 of the Upper Namoi Alluvium (Mooki Valley – Quirindi-Pine Ridge Road to Breeza) are found in Figure 46. Declining recovery is evident in all bores, with recovery at or equal to record lows in all bores. Step downs in recovery levels can be seen to correspond to periods of low rainfall, however, water levels have not recovered to previous levels prior to the droughts. This indicates that usage during wetter periods may be equal to recharge, while during dry periods extraction is draining storage. The declining trend is least regular in bore GW030087 at the upstream end of the zone, close to Quirindi Creek. This bore has been shown to have strong correlation with rainfall trends. Pipe 1 of GW030012 was dewatered in 2003 and has not recovered since.

Representative hydrographs for Zone 9 of the Upper Namoi Alluvium (Cox's Creek – Upstream of Mullaley) are found in Figure 47. These bores have been shown to be strongly influenced by climate (DIPNR 2006). The influence of extraction is seen in bore GW036601 after the mid 1990's. There may be some slight decline in this bore.

Representative hydrographs for Zone 12 of the Upper Namoi Alluvium (Kelvin Valley) are found in Figure 48. Recharge in this zone is likely to be from the basement rock, rather than from surface infiltration (DIPNR, 2006), with groundwater flowing through to Zone 4. A rising trend is seen in the hydrographs for GW036432, GW036418 and GW036322 (located in the downstream end of the catchment) prior to 1994, after which point the impact of extraction can be seen. Since this time there has been a declining trend in the hydrographs. In GW036418, the upper aquifer has become unconfined. GW036307 and GW036415 are located in the centre of Zone 12 and show an upwards leakage potential. These bores both show dewatering occurring in the upper monitoring unit.

Table 16
Summary of Hydrograph Analysis for the Upper and Lower Namoi Alluvium

GMU	Zone	Summary of Hydrograph Analysis
Upper Namoi	1	Current recovery poor, in need of major recharge event.
	2	Record drawdowns and decline in water levels. Strong evidence of leakage from upper monitoring unit to lower monitoring unit.
	3	Most bores in significant decline, with a stepdown in recovery evident since 2002-2003. Rising groundwater levels are evident on the eastern edge of Zone 3, and some bores where groundwater had been drawdown have shown some recovery recently.
	4	Some decline evident in all bores, except a site east of Boggabri with rising groundwater level.
	5 and 11	Decline evident in some bores, particularly in Zone 5, with pumping in Zone 5 showing some impacts on Zone 11.
	6 and 10	Groundwater head response are variable.
	7	Some slight decline in recovery evident in some bores close to the boundary with Zone 8.
	8	Significant decline shown throughout the zone with steps down in recovery during dry periods.
	9	Groundwater head response are variable.
	12	Water levels in decline throughout the zone.
Lower Namoi		Large drawdowns, with areas of greatest decline (recovered levels) between Narrabri and Wee Waa to the north of the Namoi River. Groundwater level in most bores is in decline. A few bores on the southern edge of the Lower Namoi show increased groundwater levels.

Representative hydrographs for the Lower Namoi Alluvium are shown in Figures 49-50, with locations of representative bores found in Figure 37. This analysis of hydrographs is a summary of the findings of the recently released Lower Namoi Groundwater Status Report (Smithson, 2009). GW030310 is located between Narrabri and Wee Waa and shows recovery decline of 4.3 m since development and decreasing pressure difference between pipes.

Large drawdowns are shown in GW021266 (north-east of Wee Waa), especially in the deeper monitoring unit. A reversal of hydraulic gradient between the monitoring units occurred around 1980, such that the head of the deeper aquifer is now approximately 9 m lower than that of the shallower monitoring unit. It is possible that these differences are due to measurement, however, there is certainly a head reversal occurring between pipe 3 and pipe 4. The hydrograph for GW030238 is located to the west of GW021266, north-east of Wee Waa, however, all pipes in this location show good hydraulic connection, yet also demonstrate very large drawdowns (~39 m). Both of these bores are showing declining water level recovery over time, especially in the deeper monitoring unit.

GW030238 is located to the far north of Wee Waa and is demonstrating significant water level recovery decline (28.5 m), as is GW025299, located to the north-west (11.6 m). GW025045 is to the south of this bore and screened in the upper and lower monitoring units. Decline in water levels in the lower monitoring unit is inducing leakage from the upper monitoring unit, and both are showing declining recovery in water levels. Bores GW036045 and GW025245 are located along a section to the south of GW025299 and are exhibiting similar hydrograph separation and decline in water level recovery in the lower monitoring unit. GW025141 is further to the south of these bores on the same section. Water levels in the pipes are in poor hydraulic connection but declining water level recovery in the lower monitoring unit (11 m) is inducing leakage and corresponding water level decline in the upper monitoring unit; this pipe has been dewatered since 2005.

GW036255 is located to the west of the management area, in the far north above Burren Junction, where all pipes are in relatively good hydraulic connection, however hydrograph separation has been increasing with development. Water level recovery decline appears to have recovered since the mid 1990's. GW036249 is located close to Burren Junction and is showing very slight recovery decline over time. GW036320 is the furthest west of the representative monitoring bores, located to the east of Cryon. There is hydraulic separation between an upper and deeper monitoring unit, with the deeper unit showing recovery decline of ~9 m.

5.3.2.2 Historical Water Level Variation

Maps of change in water level recovery are shown in Figures 51 – 64[1]. The maps have been divided into time intervals based around the key date of 2006, as the catchment management targets require either stability or improvements from 2006. The first series of maps (Figures 51 – 58) shows the change in water level recovery prior to 2006, with the

[1] Raster interpolation of the water level data was completed using the Inverse Distance Weighted Method in ArcGIS with a fixed radius of 3, power of 2 and a minimum number of 1 point

majority of maps comparing the 1978 levels to 2006 levels. As there were no monitoring bores in Cox's Creek at this time, another map has been generated for the Upper Namoi comparing 1988 levels to 2006 levels (though it should be noted that data is still only available for the downstream end of Cox's Creek. The second series of maps (Figures 59-64) show the change in water level recovery for 2006 to 2008.

The change in water level recovery for the upper monitoring unit of the Upper Namoi is shown in Figure 51, while Figure 52 shows Zone 3 of the Upper Namoi at higher resolution. While these figures show some water level recovery decline from 1978 – 2006 across most of the Upper Namoi, the most affected area is clearly Zone 3 (up to 15 m decline in water level recovery), with Zone 8 also showing significant decline (up to 13 m). This map can be compared with Figure 54, which shows the water level recovery decline from 1988 – 2006. Over this period, significant decline can still be seen in Zone 3 and also in Zone 12, where much of the development appears to have occurred during the early 1990's.

The change in water level recovery for the upper monitoring unit of the Lower Namoi is shown in Figure 53. The area of greatest water level recovery decline can be seen on the north-south section around Wee Waa, with the greatest decline across the whole catchment found on the alluvial boundary to the far-north of Wee Waa.

Less data is available for the lower monitoring unit of the Upper and Lower Alluvium. It is therefore important to be aware of the location of actual data points, rather than simply observing the colours of the contouring on the map. Figure 55 shows the change in water level recovery for the lower monitoring unit of the Upper Namoi, while Figure 56 shows Zone 3 of the Upper Namoi at higher resolution. The available data again shows Zone 3 and Zone 8 to be the areas of greatest water level recovery decline. Where the data is available in Zone 3 (compare Figure 52 to Figure 56), it appears that the drawdown is greater in the lower monitoring unit, indicating that extraction in the lower monitoring unit may be causing leakage from the upper monitoring unit.

The change in water level recovery for the lower monitoring unit of the Lower Namoi is shown in Figure 57. The area of most decline is again seen in the section around Wee Waa, with the greatest drawdown in to the south-east of Wee Waa. The only monitoring bore shown to be intersecting the lower monitoring unit in the far north section is not showing decline (compare with Figure 53), however Figure 53 does show that the areas of decline in the Lower Namoi are very localised.

Figures 59 – 64 show the change in water level recovery from 2006 – 2008. These maps show that there has been little decline in the seasonal water level recovery point in the upper or lower monitoring units of the Upper Namoi during this time. A few isolated patches of decline can be seen in Zone 3 (Figure 60). In comparison, water level recovery decline has been much more widespread in the Lower Namoi, with the region around Wee Waa showing mostly 2 -3 m water level recovery decline in the upper monitoring unit (Figure 61). While there is less data in the lower monitoring unit, it seems that the decline is even more widespread.

In areas of extreme water level recovery decline coupled with clay soils, there is a risk of consolidation of sediments. Hydrographs from bores with more than 20 m water level recovery decline between 1978-2006, 10 m between 1988-2006 and 5 m from 2006-2008 were examined in more detail to determine whether the decline might pose a genuine risk of consolidation. Bores identified in this analysis that may need further investigation in the future are summarised in Table 17.

Table 17
Bores with Decline of Recovered Levels Indicating Possible Risk of Consolidation

Bore No.	Pipe	Start Year	End Year	Final SWL (m)	Average Screen Depth (m)	Decline of recovered levels (m)
GW025054	2	1978	2006	46.5	102.77	-20.49
GW025055	3			48.05	98.08	-20.62
GW030222	1			52.18	108.19	-20.08
GW030222	2			52.36	97.63	-20.36
GW030223	2			52.06	78.64	-20.11
GW036045	3	1988	2006	46.63	62.2	-11.55
GW036149	1			23.35	220.19	-11.95
GW036149	2			24.5	208.04	-13.15
GW036149	3			27.8	169.99	-15
GW036149	4			26.51	145.33	-13.39
GW036150	1			25	206.87	-14.15
GW036151	2			25.38	185.94	-14.26
GW036166	2			25.65	194.78	-14.67
GW036166	3			25.44	176.47	-14.39
GW036167	2			21.12	232.03	-10.5
GW036167	3			26.1	198.54	-14.63
GW036193	3			27.38	150.81	-13.58
GW036215	2			22.32	201.67	-11.56
GW036215	3			22.4	177.67	-11.52
GW036266	1			19.65	250.7	-10.75
GW036266	3			19.73	158.4	-10.3

5.3.3 Combined Risks

The major risk area identified both in terms of water quality and water level pressures is Zone 3 of the Upper Namoi, which is experiencing both significant increases in salinity and long term decline in water levels. Comparing Figures 34, 36 and Figure 52, it is evident that the areas of greatest salinity increase coincide with those areas of greatest drawdown. Historical water level has been compared with salinity for several bores within Zone 3 and are shown in Figures 65 – 67. All of these bores are WRL target bores and can be found in Figure 5, with the exception of GW036213, which is located on the western side of the Mooki River just to the north-east of GW036210.

At site GW036213 (Figure 65) sharp increases in salinity occurred above 40 m occurring from 2002, corresponding to a distinct decline in water level in the lower pipes during the drought at that time. At GW036151 (Figure 65) there was a peak in salinity in Pipe 1 (~40 m depth) at the same time (around 2002), which also corresponds to a distinct water level recovery decline. After this time, water levels appear to stabilise at this new level and salinity starts to decline again. Bore GW036166 (Figure 66) shows a similar pattern of increase in Pipe 1 (~47 m depth). Although there are not as many data points to determine the time of increase, it does seem that it may have followed a similar pattern to GW036213 and GW036151. Pipe 2 (79 m) has also increased salinity significantly; water from Pipe 1 and Pipe 2 is no longer suitable for cotton irrigation (7,700 µS/cm). GW036190 is again similar to the other 3 bores examined. Salinity increase in Pipe 1 (32 m depth) appears to correlate with the water level recovery decline around the year 2001-2002, and then stabilises. This pattern seems to indicate that salinity increases in this area may be associated particularly with periods of large extraction during drought periods, although there is not enough salinity data to confirm this.

GW036200 (Figure 67) is located further away from the river on the edge of the alluvium and is showing significantly different trends. Water levels have an overall rising trend in all pipes (~87 m and above), although water levels have been in decline since 2000. Salinity has been increasing at depth, however, while salinity increased prior to 2002 in Pipe 2 (~44 m depth) it has since decreased. The period of increasing salinity appears to be associated with increasing water levels. Water levels in this bore does not show any strong pumping influence.

Based on decline in water level recovery, there may also be significant risk in Zone 8 of the Upper Namoi, and north of Wee Waa in the Lower Namoi, however, no corresponding historical groundwater salinity data was available to compare. Soil salinity (Figure 31) in the area of drawdown in Zone 8 (Figure 51) is moderate, while soil salinity in the majority of the Lower Namoi is high and therefore both areas appear to be at risk from salinisation. The Lower Namoi around Wee Waa appears to be at increased risk due to the greater intensity of irrigation in that area (Figure 30).

In summary, based on available information, the areas of groundwater resources that are considered to be at risk are:

- Upper Namoi – Zone 3 due to groundwater salinity and levels
- Upper Namoi – Zone 8 due to groundwater levels and moderate soil salinity
- Lower Namoi – north of Wee Waa due to groundwater levels and high soil salinity
- Lower Namoi – across GWMA, due to high soil salinity and near Wee Waa the greater intensity of irrigation.

5.4 Recommendations for Future Surveys

Based on the analysis of risks in the catchment, future surveys could be beneficially expanded in several ways:

- A further round of groundwater sampling of monitoring bores should be completed over the growing season (periods of high and low stress) to determine if there are definite trends in water quality response to a pumping season (see Section 4.2.2.3)
- Further analysis and verification of the connectivity method should be completed and more pipes intersecting the lower monitoring unit should be selected for ongoing monitoring
- Monitoring density should be increased in areas of high risk that are currently poorly covered i.e. Zone 8 of the Upper Namoi, and the Lower Namoi to the north of Wee Waa.
- Ideally, future surveys would also be expanded to include additional GWMA's not currently included in the survey (eg. fractured rock areas).

These recommendations are incorporated in the strategic monitoring plan in Section 6.

6. STRATEGIES FOR BEST PRACTICE GROUNDWATER MONITORING

This section aims to outline guidelines for a best practice monitoring strategy to improve assessments and best management responses to groundwater conditions. Standard monitoring guidelines currently applied in Australia and the MDB have been tailored for the Namoi catchment by identifying a series of triggers that will identify adverse risks and will involve irrigators and the community. These guidelines address both the practicalities and expense of obtaining groundwater data and the quantitative evaluation of monitoring data to identify risks and provide early warning of the degradation of the resource.

Information regarding the availability of monitoring data and general information about groundwater monitoring framework design were found in Timms *et al.* (2009). This section gives more specific recommendations for continuing and improving this monitoring program.

6.1 Groundwater Monitoring Strategy Concepts

6.1.1 Levels of Best Management Practice

The Cotton CRC is currently redefining best management practices for the cotton industry in Australia: myBMP; a web-based system to provide scientific information and assessment tools to growers, is in the final stages of development (S. Higgins, pers.com). This system is based on four levels of progress as outlined below:

- Level 1 Practices are legal requirements and industry protocols
- Level 2 Practices are considered practices growers should be adopting as a minimum and is certification standard for the cotton industry
- Level 3 Practices are considered above standard, and ones growers should be working towards achieving
- Level 4 Is aspirational.

This BMP system includes worksheets designed for individual growers to rate and benchmark their own farming practices and includes components relevant to groundwater monitoring. However, best management practice for groundwater monitoring is needed not only at individual farming scales in the Namoi catchment but also at regional, subcatchment and community scales. The concept of progress levels used by the Cotton CRC can be usefully adopted for this larger scale groundwater monitoring program, to complement those being created for individual growers. This recognises achieving best management practices may take time, and may be challenging within current budgetary constraints, yet useful steps can be taken along the path to achieving the highest level of best management practice.

6.1.2 Purpose of Groundwater Monitoring

It is important to identify the purpose(s) for groundwater monitoring. An effective groundwater monitoring program is designed to satisfy the purposes intended for the data, and is practically achievable within the available funding, personnel and equipment. The purpose of the groundwater monitoring program influences the frequency and duration of monitoring, sampling and the analysis of data.

6.1.3 Frequency and Duration of Monitoring for Various Purposes

The frequency and duration of groundwater monitoring is dependent on the issues being examined (i.e. the purpose) and the response of the groundwater system to change. The frequency of monitoring may also depend on the stage of a project and environmental assessment requirements. For example, monitoring should be designed specifically for: establishing baseline water quality and on-going monitoring of significantly changed land use where groundwater contamination is a possibility.

Duration, and continuity of monitoring is equally important to the frequency of monitoring, although most groundwater quality monitoring is limited to a short period.

6.1.4 Sampling

Groundwater sampling and analysis is expensive and needs to be undertaken strategically to fit the purpose of monitoring. The cost of acquiring a sample will be affected by the distance between bores and accessibility of the bores, purge time required prior to sampling and the cost of laboratory analyses to be completed. As much of the cost of the sample will be within the actual labour time required to collect the sample, it may be more efficient and beneficial in the long run to perform more analyses on the samples; however a trade-off is required between the number of bores that can be sampled and the analyses that are performed.

Analysis must be completed by laboratories that are NATA registered for the analyses being conducted. Standard sampling procedures must be used to ensure the integrity of the data (see Appendix A3).

6.1.5 Data Analysis

Appropriate analysis of data is crucial to the effectiveness of any monitoring program. Data must be comparable in terms of locations and parameters, so that any changes within a system over time can be determined. Any triggers adopted must be meaningful within the context of available (often limited) data. It is difficult to parameterise baseline conditions with confidence in a groundwater catchment setting over such a large heterogeneous area, and therefore is often only possible to try and determine if there is an ongoing trend in the data and whether that trend is significant.

6.2 Catchment Scale Groundwater Monitoring

This project has helped to more clearly identify areas of risk in the Upper and Lower Namoi Alluvium of the Namoi catchment in terms of water levels and salinity and to identify knowledge gaps in the Namoi catchment. Based on this information, catchment scale groundwater monitoring needs to be reviewed and adapted to suit the ongoing needs for information about catchment conditions. This section gives recommendations for ongoing best practice groundwater monitoring for the Namoi catchment. Best practice groundwater monitoring is outlined for three progress levels of monitoring relevant to the purposes of monitoring defined in the next subsection.

6.2.1 Purpose of Monitoring

This project is directly addressing data gaps for groundwater level and groundwater quality that were identified in Timms *et al.* (2009).

The primary purposes of this groundwater monitoring program are:

- Detect changes in groundwater levels and salinity
- Determine if changes are significant to beneficial use of groundwater
- Establish groundwater benchmark and trigger values for action
- Assess the response of extraction
- Identify “hotspot” areas that are sensitive to impacts.

This monitoring program would need to be reviewed and updated, should any other purposes be added to this list.

6.2.2 Data Report Card Across the Catchment

A basic report card of data availability for each GWMA based on analysis of the database developed by WRL is given in Table 18. Given the significance of the resource, there has been very little collection of water quality data in the Lower Namoi Alluvium. This table suggests that nutrient and agrichemical data collection is sparse across the catchment. This has been used to inform the levels of best practice monitoring identified for site selection and parameters in particular.

Table 18
Water Quality Data Availability from Monitoring Bores across the Namoi Catchment

GMU	Zone	EC		Major Ions[1]		Agrichemicals[2]		Nutrients[3]		Total No. Bores		Ratio ^
		No. Data Points	No. Bores	No. Data Points	No. Bores	No. Data Points	No. Bores	No. Data Points	No. Bores	Monitoring *	Production #	
N01 Lower Namoi Alluvium		503	22	424	22	1	1	1	1	443	868	2
N04 Upper Namoi Alluvium	1	191	31	211	29	3	3	3	3	14	73	**5.2**
N04 Upper Namoi Alluvium	2	247	107	223	98	14	9	14	5	75	138	1.8
N04 Upper Namoi Alluvium	3	1332	176	1288	160	23	13	131	53	107	295	2.8
N04 Upper Namoi Alluvium	4	823	221	751	189	26	19	49	37	128	465	3.6
N04 Upper Namoi Alluvium	5	670	95	591	92	2	2	3	2	76	197	2.6
N04 Upper Namoi Alluvium	6	315	52	298	39	15	7	13	7	27	105	3.9
N04 Upper Namoi Alluvium	7	31	19	24	14	-	-	-	-	19	50	2.6
N04 Upper Namoi Alluvium	8	893	117	843	107	6	6	6	6	68	208	3.1
N04 Upper Namoi Alluvium	9	62	39	53	30	7	6	11	6	35	85	2.4
N04 Upper Namoi Alluvium	10	-	-	-	-	-	-	-	-	-	-	
N04 Upper Namoi Alluvium	11	154	27	155	28	-	-	-	-	16	55	3.4
N04 Upper Namoi Alluvium	12	81	13	75	9	-	-	-	-	19	46	2.4
N05 Peel Valley Alluvium		243	149	231	142	-	-	18	8	58	653	**11.3**
N23 Miscellaneous Alluvium of the Barwon Region		55	47	65	49	-	-	-	-	7	127	**18.1**
N601 GAB Intake Beds		138	94	162	103	-	-	-	-	13	80	**6.2**
N604 Gunnedah Basin		263	182	240	168	2	2	4	4	25	96	3.8
N608 Oxley Basin		235	144	163	110	16	7	24	10	34	124	3.6
N63 GAB Alluvial		122	31	124	32	1	1	1	1	4	7	1.8
N805 New England Fold Belt		151	102	154	99	-	-	1	1	17	139	**8.2**
N813 Warrumbungle Tertiary Basalt		1	1	1	1	-	-	-	-	-	-	
N814 Liverpool Ranges Basalt		253	214	26	23	6	3	6	3	7	31	4.4
N819 Peel Valley Fractured Rock		-	-	192	150	-	-	2	2	76	408	**5.4**
Total		**6763**	**1883**	**6294**	**1694**	**122**	**79**	**287**	**149**	**1268**	**4250**	

* Monitoring bores include groundwater exploration bores from DWE registered bore database. The current status of these monitoring bores is unknown. A proportion of these monitoring bores may be currently monitored. Some bores may not be accessible, or have corroded, collapsed, silted intake screens or otherwise unsuitable to provide useful data.
# Production bores include irrigation and town water supply from DWE registered bore database.
^ Ratio of production bores to monitoring bores.
[1] Calcium used as reference parameter to infer collection of major ion dataset
[2] Atrazine used as reference parameter to infer collection of agrichemical dataset
[3] Nitrate as N used as reference parameter to infer collection of nutrient dataset

6.2.3 Site Selection

Criteria for selecting representative bores for sampling in this project included the following:

- Areas where a change in water quality would increase the risk of change in beneficial use class
- Coverage of groundwater management zones
- Data availability from previous monitoring
- Proximity to major groundwater extraction
- Proximity to river recharge sources
- Groundwater quality changes identified
- Proximity to significant salt sources.

Results of this sampling project indicate that this set of representative bores should be expanded according the following criteria:

- Further analysis and verification of the connectivity method should be completed and more pipes intersecting the lower monitoring unit should be selected for ongoing monitoring
- Monitoring density should be increased in areas of high risk that are currently poorly covered i.e. Zone 8 of the Upper Namoi, and the Lower Namoi to the north of Wee Waa.
- Ideally, future surveys would also be expanded to include additional GWMA's not currently included in the survey (eg. fractured rock areas).

Those bores used as representative bores for groundwater resource status updates (see Section 4.2.2.1) should be considered first for inclusion into the future groundwater monitoring program.

Table 20
What Sites Should be Monitored in the Namoi Catchment for BMP Groundwater Monitoring?

Monitoring Level	Practice
Basic	Representative bores for groundwater level every ~6 weeks and significant sites with continuous telemetry monitoring. Groundwater salinity monitoring* several times per year at a limited number of bores in zones.
Moderate	As above plus: • Additional representative bores with continuous telemetry monitoring • Groundwater salinity monitoring at the start of each irrigation season (annual) in representative bores in all GWMAs/zones identified at risk of groundwater salinisation i.e. Zone 3 and Zone 8 of Upper Namoi, and Lower Namoi to north of Wee Waa
High **	As above plus: • Groundwater salinity monitoring at the start of each irrigation season (annual) in bores that have been monitored in this project (covers most but not all alluvial GWMAs) with addition of bores in areas of high risk and greater coverage in lower monitoring unit. • Install additional monitoring bores in GWMAs that are currently not monitored for groundwater level or salinity.[#]

* Groundwater salinity at monitoring bores should include on-site measurement of basic field parameters including EC, pH and temperature, and laboratory analysis of major ions. Automated monitoring of EC is not possible in monitoring bores due to stagnant water.
** Berhane & Tennakoon (2003) recommended that approximately 10% of monitoring sites in the Barwon Region should be selected for a primary monitoring network of groundwater quality to allow analysis of long term groundwater quality trends.
[#] Monitoring bore coverage analysis, as indicated by the ratio of production bores to monitoring bores suggests that additional monitoring points may be required in the Peel Valley (both alluvium and fractured rock areas), the New England Fold Belt, GAB Intake Beds and the Miscellaneous Alluvium of the Barwon Region (see Timms *et al.* 2009).

In addition to bores sampled for this groundwater monitoring program, groundwater samples are also currently being obtained for other specific projects in the Namoi catchment. Rather than duplicating efforts, agreements should be made where possible to access data from other projects and incorporate them into this monitoring program. These projects include, but are not limited to:

- Monitoring of groundwater salinity below the Cryon Plains by DECCW.

- Research investigations in the Maules Creek area by UNSW Connected Waters Initiative.
- Research investigations in the Cockburn Creek area by Cook *et al.* (2007).
- Coal and gas exploration and monitoring programs in various areas.

6.2.4 Parameters

The parameters that should be monitored in the Namoi catchment for BMP groundwater monitoring are outlined in Table 19.

Table 19
What Parameters Should be Monitored in the Namoi Catchment for BMP Groundwater Monitoring?

Monitoring Level	Practice
Basic	Groundwater Level Groundwater salinity including on-site measurement of basic field parameters including EC, pH and temperature
Moderate	As above plus: • laboratory analysis of major ions
High	As above plus: • periodic laboratory analysis for nutrients and agrichemicals

The monitoring level of parameters may be varied according to the frequency of monitoring at one site. For example, in areas of High frequency monitoring, a High level of parameters monitoring may only be appropriate once a year, Moderate four times a year, and Basic for the remainder of the monitoring events.

6.2.5 Frequency of Monitoring

A basic indication of how frequently water level and water quality parameters should be measured is given in Table 20 and Table 21. It would be valuable to complete a further round of groundwater sampling of representative monitoring bores over the growing season (periods of high and low stress) to determine if there are definite trends in water quality response to a pumping season (see Section 4.2.2.3).

The frequency of monitoring required may be varied for selected sites and parameters. It may be appropriate to apply Basic frequency of groundwater quality monitoring in low risk areas with a Moderate level of parameters, and Moderate frequency in hotspot areas with a Moderate level of parameters.

Table 20
How Frequently Should Water Level be Monitored in the Namoi Catchment for BMP Groundwater Monitoring?

Monitoring Level	Practice
Basic	Quarterly
Moderate	6 weekly
High	6 weekly at sites requiring basic resource monitoring Daily readings at sites with risk of groundwater quality impacts and significant drawdowns

Table 21
How Frequently Should Water Quality Parameters be Monitored in the Namoi Catchment for BMP Groundwater Monitoring?

Monitoring Level	Practice
Basic	Annual
Moderate	Twice per year or Quarterly*
High	Monthly

* Quarterly allows examination of trends in water quality response to a pumping season and better definition of baseline trends.

This monitoring is considered basic resource monitoring and therefore needs to be ongoing for as long as the groundwater resource is utilised.

6.2.6 Sampling

Standard sampling procedures must be used to ensure the integrity of the data (see Appendix A3). This includes purging of bores prior to sampling or use of appropriate low flow sampling techniques. Analysis must be completed by laboratories that are NATA registered for the analyses being conducted. It is not considered appropriate to have levels of best management practice for sampling techniques as the value of data collected will be compromised by lower standards.

6.2.7 Data Analysis

As the Catchment Target for Surface and Ground Water Ecosystems (see Section 2.1) requires an "improvement in the condition of surface and ground water ecosystems" from 2006, future data analysis should use the data prior to 2006 as the reference point for establishing catchment baselines.

The following analysis, completed in this report, are considered basic to understanding the status of the resource and can be completed if a Basic monitoring level is conducted:

- Hydrograph plotting and analysis
- Mapping of change in recovery levels from 2006
- Plotting of historical EC.

A Moderate and High level of site selection for water quality monitoring will also allow the following to be completed:

- Mapping of change in EC from 2006.

Appropriate data analysis is dependant on the monitoring level adopted. The frequency of monitoring and parameters selected will impact on the analysis that can be completed.

6.2.8 Database Development and Accessibility

WRL has developed two databases (one for water quality and one for water levels) for the Namoi catchment in MS ACCESS, with pre and post processing of data using Python scripts and quality checking and correcting where possible. All data and information obtained during the project has been provided with this report in an appropriate digital format for upload into public information systems maintained by the Namoi CMA and DWE.

All future monitoring data must continue to be included in these databases with appropriate quality control and checking. Of vital importance is the need to be consistent with terminology and formatting, in particular the need to associate data with the correct Location Codes and Well Codes. A detailed description of the database standards and guidelines is given in Appendix A10.

6.3 Grower Groundwater Monitoring

As indicated by the GHD Hassall grower survey, there are a range of opinions as to the value of community groundwater monitoring. Community monitoring is the aggregation of sample data from a number of grower bores around the catchment. The samples may be collected either by the growers, or by an independent team that uses standard protocols to collect samples. The WRL team considers that community monitoring is of limited value in a scientific context but that such a program may contribute to greater community appreciation of groundwater status. One reason for this position is the difference in monitoring bore and irrigation bore design (Figure 68). As irrigation bores may be screened across several monitoring units, they only give a mixed sample; often the screen depths are not even known.

As described in the GHD Hassall report, a number of monitoring options were presented at community groundwater workshops:

1. Enhanced data gathering and communication by DECCW
2. Supplement with additional independent data gathering
    - from ***monitoring bores*** *and / or* from ***grower pump bores***
3. Supplement with monitoring by groundwater users of ***grower pump bores***
4. Supplement with independent analysis/ communication
5. No change.

A BMP for groundwater quality monitoring of an irrigation bore has been developed by WRL for inclusion into ‘myBMP’ (see Section 6.1.1) so that growers are able to monitor groundwater levels and groundwater quality at a target level. This is shown in the following box.

IRRIGATION BORE BMP WORKSHEET

Level 1

- Provide a water quality report in accordance with Departmental approval for water supply work[1]
- Bore construction and abandonment of old bores in accordance with Departmental bore licence[2] and guidelines for Australia[3]

Level 2

- To maximise yields from crops, use bore water for irrigation within appropriate guidelines[4] for salinity (EC). Mix with alternative water sources where appropriate and available.
- Measure water level and groundwater salinity (EC or electrical conductivity) at the start and end of each irrigation season using minimum standard methods[5]
- Record ground water level and groundwater salinity for detection of potential trends over time

Level 3

- To maximise irrigation yields use bore water within appropriate guidelines[6] for specific ions, hardness and sodium adsorption ratio. Mix with alternative water sources where appropriate and available.
- Continuous measurement using a automated logger for bore water level and quality (EC)
- Collect samples at the start of each irrigation season for laboratory analysis[7] of groundwater salinity and major ions by following standard methods[8]
- Laboratory testing of major water quality characteristics and comparison with guidelines for irrigation use (Major ions – sodium, magnesium, potassium, calcium, chloride, sulfate and alkalinity)

Level 4

- Continuous sampling using an automated logger for bore water level and quality (EC) with telemetry to office and/or website.
- Laboratory testing at the start of each irrigation season of groundwater samples for nutrients (nitrate and phosphate) and agrichemicals (eg atrazine).
- Adoption of advanced guidelines[9] for bore construction with monitoring access (Resource fact sheets -include water level dip tubes and sampling tap in bore design)

---

[1] The water supply approval holder is to provide a standard report on water quality as requested by DECCW. Contact DECCW water licensing for advice on 1800 353 104 or www.water.nsw.gov.au and search "water licensing enquiries" and "groundwater licences frequently asked questions"

[2] Contact DECCW water licensing for advice on 1800 353 104 or www.water.nsw.gov.au and search "water licensing enquiries" and "groundwater licences frequently asked questions"

[3] "Minimum Construction Requirements for Water Bores in Australia" is available for download at www.water.nsw.gov.au and search for "Driller's licences"

[4] See Table 1 of this report

[5] Minimum standard methods include purging stagnant water from the bore casing for 15 minutes and calibration of EC meter. See Fact Sheet "DIY Groundwater Monitoring" on Cotton CRC website and Appendix A9 of this report

[6] See Appendix A4 sample grower report and Appendix A9 of this report

[7] Laboratories registered with the National Association of Testing Authorities (www.nata.asn.au) can provide groundwater tests.

[8] Standard methods include purging stagnant water by calculating the volume of water in the bore casing and pumping 3 times this volume, calibration of conductivity meter, using a laboratory supplied sampling bottle and delivering chilled samples for analysis within holding times. See Fact Sheet "DIY Groundwater Monitoring" on Cotton CRC website and Appendix A9 of this report

6.4 Identifying Risk and Resource Degradation

Identifying risks and resource degradation is a key goal of this monitoring program. While it is possible to identify areas of risk and resource degradation with basic data analysis techniques, it is difficult to define the point at which this is significant i.e. to define triggers, especially without adequate baseline data. Defining adequate triggers will also only be possible if a certain frequency of groundwater monitoring is adopted. At the least, a Moderate monitoring level frequency of groundwater quality monitoring must be adopted to enable risk triggers to be established.

6.4.1 Risk Triggers

Risk triggers for water level decline are tied into Water Sharing Plans and are based on the relationship between recharge and usage. Trading in water licenses has also been embargoed in some areas of extreme drawdown and stress. The aim of this section is therefore to establish triggers for water quality parameters.

The major concern for the catchment is water declining in quality such that the beneficial use is degraded. Given the lack of data, it is not considered appropriate to apply advanced statistical methods to the problem. It is recommended that EC be used as the primary parameter for a trigger at this time and that the following simple triggers be adopted on a bore-by-bore basis:

1. EC should not increase such that the mean EC in any given year is in a degraded beneficial use[2] category in comparison to the lowest historical beneficial use category.
2. EC should not increase such that the most recent value is the highest recorded and the mean EC in any given year is a certain percentage greater than the mean EC from the prior year. The cutoff percentages will vary on a sliding scale based on the mean EC value, as seen in the table below:

EC Range (µS/cm)	Percentage Cutoff
0 – 1500	30%
1500 – 8000	20%
> 8000	10%

[2] The guideline values for beneficial use categories of concern must be chosen on a study-by-study basis (see Table 1).

3. EC should not increase over a 5 year period such that Mann-Kendall tests show an increasing trend and that the difference in yearly mean values over the 5 year period is greater than 10%.

A selection of bores was examined to test the application of these triggers with a summary of the data shown in Table 22. A corresponding plot of historical EC for these bores is given in Figure 69. This table and plot show that the triggers appear to identify significant trends of increasing EC reasonably well. It also demonstrates that while some bores may appear to have statistically significant increases in EC (eg. Upwards trending Mann-Kendall values), that these trends may not always be practically significant. For example, while bores GW030061 and GW030168 have upwards Mann-Kendall trends, examination of the data and plot shows that recent values are within historical ranges.

Where a trigger is exceeded, and the monitoring level frequency has been Basic (annual), the first response should be to review and verify the data and then to increase the monitoring level frequency to Moderate or High.

Where salinity changes have already been identified, such as in Zone 3 of the Upper Namoi Alluvium, no baseline statistics can be determined for use in triggers. However, in areas where no changes have been identified, basic frequency of monitoring over a period of at least 6 years (or moderate frequency over 2 years) will allow baseline means and ranges to be determined which can then be incorporated into future triggers when the monitoring program is reviewed. Given that the dataset will still be limited, the mean value should be calculated from the upper Confidence Interval (CI) estimate of the mean thus reducing the uncertainty regarding the estimated mean (see Section 2.3.2).

Table 22
Practical vs Statistical Significance of EC Change – An Examination of Suggested Triggers

Bore	Pipe	GWMA/Zone	Practical significance of EC change							Statistical significance of EC change			
			Max Value (uS/cm)	EC value 1 (uS/cm)	EC value 2 (uS/cm)	% change	New exceedance of a guideline value*	Change in Beneficial Use Category? **	Trigger?	Significant at 90% confidence?	Mann Kendal Trend	No. of Points	Max Value Last
GW036314	1	(001)	29700	28500	26500	-7	No	No	No	Yes	Down	16	No
GW036314	2		3690	2450	3290	34.3	No	No	No	Yes	Down	16	No
GW036314	3		5070	4361	3200	-26.6	No	No	No	Yes	Down	18	No
GW036398	1	?	7190	4950	5140	3.8	No	No	No	Yes	Down	14	No
GW036398	2		1440	1190	1140	-4.2	No	No	No	Yes	Down	14	No
GW036166	1	(004) /3	14200	14200	11590	-18.4	No	No	No	N/A	No	5	No
GW036166	2		8830	3450	8830	155.9	Yes	Yes	Yes	N/A	No	2	Yes
GW036166	3		833	833	831	-0.2	No	No	No	N/A	No	3	No
GW036200	1	(004) /3	1490	1430	1490	4.2	Yes	No	No	N/A	No	2	Yes
GW036200	2		1750	1750	1308	-25.3	No	No	No	N/A	No	3	No
GW036200	3		1413	1380	1413	2.4	No	No	No	N/A	No	3	Yes
GW036202	1	(004)/3	4550	906	2661	193.7	Yes	No	No	N/A	No	6	No
GW036213	1	(004)/3	5300	4720	4550	-3.6	No	No	No	N/A	No	6	No
GW036213	3		1000	949	908	-4.3	No	No	No	N/A	No	7	No
GW036214	1	(004)/3	3680	3150	3680	16.8	No	No	No	N/A	No	2	Yes
GW036214	2		3350	966	3350	246.8	Yes	Yes	Yes	N/A	No	2	Yes
GW030000	1	(004)/3	1110	940	1047	11.4	No	No	No	Yes	Up	17	No
GW030061	1	(004)/6	2350	1532	1362	-11.1	No	No	No	Yes	Up	39	No
GW030168	1	(005)	392	392	363	-7.4	No	No	No	Yes	Up	7	No
GW030168	2		390	390	367	-5.9	No	No	No	Yes	Up	6	No
GW036213	2		2740	2100	2740	30.5	No	No	Yes	Yes	Up	5	Yes

See notes over page

*Guideline value in Table 1 of Report 2
**Trigger if EC change >30% (0-1500 uS/cm), >20% (1500-8000) or >10% (8000), Table 14, Table 6.4.1 in Report 2
EC value 2 = last recorded value in sequential dataset
EC value 1 = second last recorded value

6.4.2 Data Evaluation

Due to the heterogeneity of the catchment and the lack of baseline data, the monitoring data from multiple bores cannot be aggregated to increase the available sample size for statistical analysis, therefore historical data must be analysed on a bore-by-bore basis. Mapping may still be used as a means to view hotspots and particular areas of interest, however, an increase in one bore cannot be used to infer an increase in another with any confidence.

6.5 Monitoring Program Review

This monitoring program should be reviewed in two years to determine the efficiency of the program and to revise the selection of sample sites and parameters and monitoring frequency. Thereafter, the monitoring program could be reviewed every five years.

7. SUMMARY AND RECOMMENDATIONS

7.1 Summary - Groundwater Monitoring and Evaluation

A strategic groundwater monitoring program in the Namoi catchment has been developed to manage and assess risks to groundwater into the future. This program is based on literature review, groundwater sampling, analysis of historical and newly collected groundwater level and quality data and an evaluation of risks to groundwater in the Namoi catchment.

This report (Report 2) builds on the findings of Report 1 (WRL Technical Report 2009/04), which reviewed the current literature regarding the Namoi catchment groundwater and provided an assessment of the groundwater monitoring framework of the area. The key issues of concern identified were decreasing groundwater levels and salinisation of groundwater for beneficial use.

Review of Groundwater Indicators and Targets (Section 2 of WRL Technical Report 2009/25)

Groundwater indicators and targets are an integral part of any groundwater monitoring program. The Catchment Target for Surface and Ground Water Ecosystems is "From 2006, there is an improvement in the condition of surface and ground water ecosystems" (Namoi CMA, 2006). The relevant Catchment Management Targets numbers two and four were to improve access to groundwater for irrigation, raw drinking water and the environment.

Under the NSW Groundwater Protection Policy (DLWC, 1998), "All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained". To determine if beneficial use is maintained and catchment management targets are being met, an early warning indicator of undesirable change is needed. A trigger is used as a means to define whether any change occurring is significant. Literature reviews of groundwater triggers found that a range of methods are used: Upper Cutoff Limits, identifying trends using graphical evaluation and non-parametric statistical techniques for limited data sets (eg. Mann-Kendall test).

The key issue with defining triggers in groundwater is the lack of data which limits the range of statistically valid techniques that can be used to define triggers. In particular, without adequate baseline data, triggers which compare current data to a prior set of 'baseline' data cannot be used. It is vital to keep in mind that while statistics may show that change is significant, a trained and experienced hydrogeologist is still needed to look at the data and determine if that change is significant from a practical point of view.

A Connectivity Index to Define Monitoring Units (Section 3)

In order to evaluate data from the Namoi catchment, a significant improvement in groundwater best practice was developed for 2D mapping and evaluation. Whilst previous reports identify alluvial aquifers based on depth limited cutoffs, a connectivity index was developed for this project to define monitoring units in the alluvium based on hydraulic behaviour during stress periods. Throughout this report, results were presented in terms of "Upper" and "Lower" monitoring units for the alluvial aquifers.

Groundwater Monitoring in 2009 (Section 4)

The following two groundwater monitoring programs were completed in 2009:

a) Groundwater sampling by growers - samples voluntarily collected by irrigators/growers in the Namoi catchment and sent to WRL for analysis

b) Groundwater sampling of DECCW monitoring bores - three sampling rounds of strategic monitoring bores by WRL staff.

A total of 79 samples were provided by growers from all across the Namoi catchment (both alluvium and fractured rock aquifers). The coverage across the catchment was diverse but sparse. The scientific value of this data was somewhat limited by incomplete information on bore location, intake depths and the practicalities of sampling methods. However, important information was obtained, showing relatively low electrical conductivity (EC) of grower bores, with most samples suitable for drinking water, and all samples suitable for irrigating mature cotton. Not all groundwater samples were suitable for irrigation of early season cotton that requires EC <1500 μS/cm. Soil structural problems (due to sodicity) were unlikely from irrigation with groundwater from the majority of these grower bores.

Groundwater sampling of Department of Environment, Climate Change and Water (DECCW) bores was completed for an average of 63 pipes over 46 sites for 3 sampling rounds in January, March and July 2009. These bores were all located in the Lower Namoi Alluvium, Upper Namoi Alluvium and Peel Valley Alluvium. The greatest depth to groundwater (>40 m) was to the north-west of Wee Waa in the Cryon region. In Upper Namoi, the depth to groundwater is greatest in Zone 3, near Curlewis and in Zone 12. Hydrographs and changes over time in groundwater levels are presented in Section 5.

Key findings with respect to groundwater quality at monitoring bores were as follows:

- Measurements of electrical conductivity (EC) showed the best quality water near the river. Poorer quality water is found to the far west of the Lower Namoi Alluvium, but also in hotspots throughout the catchment around Curlewis (Zone 3), Zone 6, Boggabri (Zone 4) and Narrabri (Zone 5).
- Overall, the salinity measured for each of the monitoring rounds for the Lower monitoring unit is lower than in the Upper monitoring unit. Areas with higher salinity correspond to those areas with higher salinity in the Upper monitoring unit (i.e. around Curlewis (Zone 3), Zone 6 and Boggabri (Zone 4).
- SAR (sodium adsorption ratio) and EC concentrations indicate that most of the water from monitoring bores could result in soil degradation if used for irrigation
- Groundwater EC values during January and March were generally similar, though in some shallow monitoring bores sampled in July, groundwater EC had increased or decreased.
- The relationship between groundwater levels and EC varied both spatially and over time. EC appeared to increase with drawdown in some bores, whilst appearing to decrease in others.

Groundwater salinity results for grower bores and monitoring bores were similar except in areas with relatively saline shallow groundwater. For example, in Zone 3 of the Upper Namoi, the relative difference between the groundwater salinity in a production bore to the groundwater salinity in the nearest monitoring bore ranged between -24% to +70%. This comparison indicates that groundwater salinity at a similar depth can vary significantly over a distance of kilometres within each Zone.

The main classes of beneficial uses of groundwater were mapped using average EC for the period 2000-2005, to provide a reference for improvements after 2006 across the catchment in the upper, lower and deeper monitoring units of the Namoi alluvium. These maps demonstrate that for the majority of the catchment, water must not be degraded below the beneficial use of drinking water.

Risks to Groundwater in the Namoi Catchment (Section 5)

Risk factors for groundwater in the Namoi catchment include high background salinity, proximity to salt sources, rate of groundwater extraction, irrigation intensity, soil type and distance from recharge sources. Mapping shows that the salt store throughout most of the Upper Namoi and Lower Namoi Alluvium is either moderate or high.

Evidence of increasing groundwater salinity in Zone 3 between the 1970's and 1990's was presented by Lavitt (1999), whose findings are confirmed and expanded by this study. Historical water quality data was compiled and analysed for average EC from 1980-1999 compared with 2000-2009. The largest increases occur east of the Namoi River in Zone 3 (eg. +123% EC average at GW036166 with a final average EC value of 8 830 µS/cm in Pipe 2), however, there were also bores in this area with no significant EC increase. Less data is available for the Lower Namoi which in general appears to be fairly stable with respect to salinity (where data is available). Only 27 bores of the 1268 monitoring bores across the catchment had sufficient data to analyse change in beneficial use before and after 2006. However, of eight bores with changed beneficial use category, degradation had occurred at one of these bores.

Hydrographs and groundwater level maps for representative bores in each zone were presented with data up to mid-2008. To evaluate catchment targets since 2006, areas with groundwater levels that are stable or require improvements were identified. In general, groundwater levels have declined over time in all areas of the catchment but there are some signs of groundwater level stabilisation over the past couple of years in some areas such as Zone 3 and in the unconfined aquifer of Cox's Creek.

In summary, based on available information, the areas of groundwater resources that are considered to be at risk with current rates of groundwater usage are:

- Upper Namoi – Zone 3 due to groundwater salinity and levels
- Upper Namoi – Zone 8 due to groundwater levels and moderate soil salinity
- Lower Namoi – north of Wee Waa due to groundwater levels and high soil salinity
- Lower Namoi – due to high soil salinity and near Wee Waa the greater intensity of irrigation.

Strategies for Best Practice Groundwater Monitoring (Section 6)

A 4 level best management practice (BMP) system was adopted to develop strategic guidelines for individual growers to monitor groundwater, consistent with the myBMP program by the Cotton Catchment Communities CRC. In a similar manner, a 3 level (Basic, Moderate, High) approach for strategic groundwater monitoring was proposed at regional and subcatchment scale.

A data availability report for each groundwater management area (GWMA) indicates that very little groundwater quality data is available for the Lower Namoi alluvium, and that useful data for at risk areas is also limited, particularly with historic records of groundwater quality that do not indicate the pipe number or depth of sampling. Recommendations were provided for each level of monitoring in terms of parameters to measure and required frequency to provide baseline data. At the least, a moderate monitoring frequency must be adopted to enable risk triggers to be established (in addition to the basic level monitoring that is current practice).

Risk triggers to provide early warning of groundwater salinity increase were developed using EC as a relatively in-expensive indicator, and a sliding scale of relative EC changes that could be assessed on a bore-by-bore basis depending on whether the groundwater is fresh or saline. EC changes of at least 10% are considered to be significant and would provide early warning of changes. A protocol for data evaluation, archiving was outlined, along with a recommendation for a review of monitoring programs after 2 years, and thereafter every 5 years. A summary of recommendations for strategic groundwater monitoring was presented in Section 7.

7.2 Summary - Grower Survey

The Grower Survey by GHD Hassall is found in Part B of this project report.

A survey and workshop series involving groundwater users in the Namoi was undertaken to seek to identify the potential to improve collection and communication of groundwater monitoring information and interest from groundwater users in participating in a community monitoring program.

Key findings were:

- Most groundwater users have a good to reasonable understanding of groundwater issues but limited knowledge of the current condition of the resource.
- Groundwater users would like to receive more regular (annually and when critical changes are detected is sufficient for most) information about groundwater condition, preferably before the start of each irrigation season.
- Some information is readily available but not all groundwater users are aware of this, many have not tried to find it.
- Many were happy with how they had received information in the past (status reports and meetings) but felt that this service had deteriorated in recent years with cut backs in the department and loss of hydrogeologists.

- Some would like to see real-time data. The telemetry program which is being set-up now was expected to help achieve this.
- Other than a few specific areas, water quality is generally considered to be good and there is more interest in groundwater levels than in quality.
- Many groundwater users informally monitor their groundwater bores but few maintain records over time.
- There is willingness but many reservations (including concerns about how the data will be used and the reliability of the data) and not great enthusiasm for a groundwater user monitoring program. There are some exceptions to this and in some localities a monitoring program may be more successful.
- Sampling by groundwater users will be more favourable if undertaken during the pumping season – the first pumping of the season (August/September) and the last (February / March) were suggested as suitable times for sampling.
- Providing and promoting a standard protocol for on-farm monitoring and data recording was suggested to enable comparison between groundwater users.

There is significant scope and demand for improving the communication of information about groundwater conditions in the Namoi. The new telemetry program will go some way to help this but is not the complete solution as it will only provide information about levels (not quality), does not provide any interpretation of trends and is limited to a relatively small number of bores.

Recommendations are:

1. Work with the DECCW NSW Office of Water to develop an approach to enhance their program of groundwater monitoring and communication in the Namoi, including potential enhancements to the new telemetry program.
2. Develop and promote protocols for groundwater users to gather and track their own groundwater data and encourage discussion of findings.
3. Improve communication and promotion of data about groundwater monitoring, using a combination of methods to distribute information at least annually before water use decisions are made for the summer season. This would include distribution of status reports, a series of winter meetings for interpretation and discussion and real time information from monitoring bores available via the internet.
4. Supplement the NSW Office of Water data by supporting additional independent monitoring, particularly a periodic program of groundwater quality analysis.

5. Further investigate the benefits, costs and implementation options of a coordinated monitoring program that would involve:
    - o Sampling at the start and potentially also the end of the summer irrigation season (i.e. August/September and February/March)
    - o Standard, robust, easy to follow methodology for sampling procedures
    - o Quality checking
    - o Centralised analysis and interpretation
    - o Rapid feedback on individual analysis and interpretation of results across region/zone (within 2 months)
    - o Comparison of findings with NOW data sets
    - o Confidentiality of data
    - o Recognition of the limitations and ownership of the data
    - o Funding of coordination and monitoring equipment.

7.3 Estimated Costs of Strategic Groundwater Quality Monitoring

Investing in strategic groundwater quality monitoring by individual growers and at a regional scale is vital to ensuring continued access to fresh groundwater resources by all users including the environment. Individual monitoring of irrigation bores by growers if done at the start of each pumping season would initially cost several hundred dollars for a water level meter and a water quality meter (EC, pH and temperature) and would subsequently cost up to $100 for each laboratory analysis of major ions. Further details are provided in Appendices A3 and A9. Costs of promoting and supporting growers to gather and track their groundwater data have not been assessed.

Regular monitoring of groundwater quality at a catchment scale is currently limited to field parameters and major ion data at a few locations at an estimated of $40,000 to $80,000 per year. It is recommended that the standard of groundwater quality monitoring is strategically increased to at least a moderate practice at an estimated cost in the order of $100,000 to $200,000 per year. A moderate standard of groundwater quality monitoring would include testing of field parameters (SWL, EC, pH and temperature) and major ions at approximately 60 key monitoring pipes twice per year, focused in areas where salinity increases have occurred, or may occur in the future.

Table 25
Estimated Costs of Strategic Monitoring

	Strategic Monitoring			
	Basic	**Moderate**	**Moderate – enhanced**	**High**
Frequency	Annual	Twice per year	Quarterly	Monthly
Parameters	SWL, EC, pH, Temp	SWL, EC, pH, Temp, Major ions (Ca, Na, K, Mg, Cl, SO_4, HCO_3)	SWL, EC, pH, Temp, Major ions (Ca, Na, K, Mg, Cl, SO_4, HCO_3)	SWL, EC, pH, Temp, Major ions (Ca, Na, K, Mg, Cl, SO_4, HCO_3) plus nutrients & agrichemicals
Where?	Cryon, Zone 8	Zone 3, 8, Cryon, Lower Namoi north of Wee Waa	Zone 3, 8, Cryon, Lower Namoi north of Wee Waa	All representative bores plus new monitoring bores
No. of samples	40	60	60	80
Field time (days)	8	12 days × 2 trips	12 days × 4 trips	16 days × 12 trips
Data points	160	1320	2640	-
Estimated Costs*	$40,000 to $80,000	$100,000 to $200,000	$200,000 to $300,000	Not costed

*Estimated current costs (2009) assumed two persons for field sampling and include the costs of travel, equipment, laboratory analysis, data processing, reporting and data archiving to a standard similar to that found in this report. The costs are estimated for an independent agency rather than local NSW Office of Water who may provide cost savings.

An enhanced moderate standard with quarterly testing would improve confidence levels of statistical baseline parameters, at a cost of approximately $200,000 to $300,000 per year. By comparison, an estimated $480,000 per year of groundwater access and usage fees for users of the Namoi alluvium sources. A high standard of groundwater quality (which has not been costed) would include more widespread testing in areas of the catchment that do not currently have monitoring infrastructure, and could include other water quality parameters such as nutrients.

The cost of moderate standard of monitoring would represent a significant increase over estimated expenditure for groundwater quality monitoring prior to 2009. A summary of estimated monitoring costs is provided in Table 25. These estimates do not include the value of monitoring bore infrastructure which is a significant capital cost. It should also be noted that the estimated costs are for independent agencies to undertake this work, although it may be possible for locally based NSW Office of Water to undertake the monitoring with some cost savings.

The estimate of $480,000 per year in fees is based on 208,000 ML/year of groundwater use assuming an access fee of $1.50 per ML and usage fee of $0.75 per ML (NSW Department of Water and Energy, Water management charges for licensed water users, February 2008). The actual trading of groundwater whether on a permanent or temporary basis provides an alternative measure of groundwater value in the order of $100-200 per ML. Finally, if there are few alternative water sources to groundwater to support the $380 million irrigation industry during drought periods, the value of this resource could amount to $1,800 per ML ($380,000,000/208,000 ML). Estimating the value of the groundwater resource for drinking water supplies and for the environment is beyond the scope of this project. Strategic groundwater quality monitoring is a critical component of the total investment in monitoring, investigating, modelling and managing groundwater resources across the entire Namoi catchment.

7.4 Community Groundwater Monitoring

Community groundwater monitoring is important to test groundwater at the point of use and promote awareness of groundwater issues. The "Groundwater Sampling in July" for this project was a success in terms of indicating relatively low salinity at the point of groundwater use and a moderate participation rate (79 samples of 200 targeted – 40% participation).

However, community monitoring programs should not be considered a replacement for catchment wide strategic monitoring. There were many reservations expressed in the workshops and interviews regarding community monitoring programs. Some groundwater users were concerned over how the information is used, while others had concerns over the reliability of the data. The scientific value of grower collected data in this project was somewhat limited by rates of participation, sparse coverage for GWMA zones, incomplete information on bore location, intake depths and the practicalities of sampling methods.

It is recommended that future community groundwater monitoring should sample at the start of the irrigation season (August-September). In addition, community groundwater monitoring should include widespread promotion, free analysis and/or supply of water quality meters and timely feedback of results and practical outcomes. Whilst it is highly desirable that the data is made available for comparison of changes in the future, the sensitivity of data gathered by growers is acknowledged. For this project, the data gathered by growers has been grouped on a zone by zone basis and is not available for future assessments.

7.5 Technical Recommendations

Based on available data and review information, the key technical recommendations of this project are as follows:

- Enhanced communication and regular updates of groundwater level and groundwater quality status are essential for growers to participate in managing the resource.
- A 4 level BMP for Irrigation Bores is recommended for growers to effectively monitor the status of groundwater at the point of use, and to maximise yield from crops by irrigating with groundwater that is of a suitable quality.
- Groundwater level monitoring in monitoring bores across the catchment is currently considered to be at a basic to moderate standard, with the introduction of telemeter sites and web access to automated groundwater level logger data a positive development.
- Groundwater quality monitoring at representative bores across the catchment is currently at a basic standard in terms of frequency, distribution of bores and parameters that are measured. It is recommended that the standard of groundwater quality monitoring be increased to a moderate level with a strategic focus on areas identified to be at risk in Zones 3 and 8 of the Upper Namoi, the Lower Namoi north of Wee Waa and other risk areas where possible.
- It is recommended that additional baseline groundwater quality data is essential to identify natural variability, and enable robust evaluation of the significance of any trends that occur. In some areas, such as Zone 3 of the Upper Namoi, significant groundwater salinity increases have occurred as determined by exceedance of guideline values, changes in beneficial use and statistical analysis, although the power of statistical techniques has been limited by inadequate baseline data.
- It is recommended to adopt indicative EC triggers on a bore-by-bore basis that identifies relative EC increases in consecutive years of 10-30%, depending on how low or high the EC value is, and whether a beneficial use category is degraded. Where a trigger is exceeded, the data should be verified and reviewed, and as a first step, increase the monitoring level from Basic to Moderate, or from Moderate to High.
- It is recommended that evaluation and mapping for this project are enhanced by further analysis of historic data that has been collated and new data that has been collected. In particular, further hydrogeochemical analysis of the data could provide valuable information on the processes that contribute to variable groundwater levels and groundwater salinity over time.
- It is recommended that the connectivity index developed for this project is enhanced by verification and 3D mapping of data. Whilst updated 2D maps presented in this report

are useful indicators, groundwater status in complex 3D systems are better understood using advanced 3D methods demonstrated by CWI research programs (eg. The and Kelly, 2009).

8. REFERENCES

Andersen, M and Acworth, I (2007), "Geochemical and Geophysical Sampling Campaign at Maules Creek – Data Report for 2006". Connected Waters Initiative, UNSW, Water Research Laboratory.

Barret C, Williams R M, and Sinclair P (2006), Groundwater chemistry changes due to mixing – Lower Namoi Valley, New South Wales.

Berhane, D and Tennakoon, T (2003), "Groundwater Quality Monitoring Review: Barwon Region". Department of Land and Water Resources, CNR2002.81

Berhane, D (2001), "Groundwater Recharge Estimation for Zone 7: Upper Namoi Alluvium Groundwater Management Area". Department of Land and Water Resources, CNR2001.108

BOM (2009), Water Information Bulletin, issue 5, 16th February 2009.

Bradd, J, Waite, D and Turner, J (1994), "Report to the Conservation and Land Management & Land & Water Resources Research & Development Corporation on Component 2: Hydrogeology Studies". University of New South Wales.

Broughton, A (1994a), "Coxs Creek Catchment Hydrogeological Investigation and Dryland Salinity Studies". Department of Water Resources.

Broughton, A (1994b), "Mooki River Catchment Hydrogeological Investigation and Dryland Salinity Studies". Department of Water Resources.

Cook, P G, Lamontagne, S, Berhane, D, Clark, J F (2007).,Cockburn River, NSW – Baseflow contribution to streams. In: Howe, P, (2007). A Framework for assessing environmental water requirements for groundwater dependent ecosystems. Report 2 Field Studies. Prepared by REM, CSIRO and SKM for Land & Water Australia.

Coram, J (1999), "Groundwater Recharge in the Mooki River Catchment, northern NSW". Draft, Land and Water Sciences Division, Bureau of Rural Statistics.

Cotton Australia (2005), Cotton Australia Annual Report 2004-2005.

Cotton CRC, (2008), Cotton CRC Catchments Website: Namoi Catchment, URL: http://www.cottoncrc.org.au/content/Catchments/MyCatchments/Namoi_Catchment.aspx, Accessed 21 April 2008.

CSIRO (2007), Water Availability in the Namoi: A report for the Australian Government form the CSIRO Murray-Darling Basin Sustainable Yields Project
Dissertation, University of Technology, Sydney. Unpublished, 551

DLWC (1998), “NSW Groundwater Protection Policy”. NSW Department of Land and Water Conservation.

DLWC (2000), Upper Namoi Valley Groundwater Status Report 1999. Draft February 2000.

DLWC (2003), Integrated Catchment Management Plan for the Namoi Catchment 2002. NSW Department of Land and Water Conservation.

DNR (2006), Lower Namoi Status Report 2004. Draft 2006.

DNR (2007), Groundwater embargoes. NSW Department of Natural Resources, Naturally Speaking Newsletter Issue 9, March, 2007.

DWE (2007), Map of Groundwater embargoed areas – Groundwater sharing plan areas. NSW Department of Water and Energy, September 2007.
http://www.legislation.nsw.gov.au/viewtop/inforce/subordleg+1035+2002+FIRST+0+N/

HydroGeoLogic, Inc. (2005), Mann-Kendall Analysis for the Fort Ord Site, OU-1 Annual Groundwater Monitoring Report, California.

Insearch Limited Report for NSW Department of Land and Water Conservation, Project No. C99/44/001, August 2001, 91p.

Ivkovic K M, Letcher R A, Croke B F W, Evans W R and Stauffacher, M (2005), A framework for characterising groundwater and river interactions: a case study for the Namoi Catchment, NSW, 29th Hydrology and Water Resources Symposium.

Kelly B, Merrick N, Dent B, Milne-Home and Yates, D (2007), Groundwater Knowledge and Gaps in the Namoi Catchment Management Area, for the Cotton Research and Development Corporation.

Kelly, B (2009), "Cox's Creek Hydrograph Analysis". UNSW Report, March 2009.

Lavitt, N (1999), Integrated Approach to Geology, Hydrogeology and Hydrochemistry in the Lower Mooki River Catchment. PhD Thesis, University of New South Wales.

LWBC (2003), Minimum Construction Requirements for Water Bores in Australia. Land and Water Biodiversity Committee.

McLean, W (2003), Hydrogeochemical evolution and variability in a stressed alluvial aquifer system: Lower Namoi River Catchment, NSW. PhD Thesis, University of New South Wales

MDBC (2004), Murray-Darling Basin Groundwater Status 1990-2000: Catchment Report for Namoi River. Murray Darling Basin Commission.

Merrick, N (2001), Lower Namoi Groundwater Flow Model: Calibration 1980-1998.

Merrick, N P (2000), "Optimisation Techniques for Groundwater Management. PhD.

Namoi CMA (2007), Namoi Catchment Action Plan Part B: Natural Resource Management Plan. Namoi Catchment Management Authority.

National Groundwater Committee (1999), The Australian National Groundwater Data.

NHMRC (2004), Australian Drinking Water Guidelines. National Health and Medical Research Council.

North Dakota Department of Health - Division of Waste Management (2009), Guideline 2 - Statistical Analysis Of Groundwater Monitoring Data From Solid Waste Management Facilities, NDDH.

NSW Government (2003), Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources 2003.

Sara, M N and Gibbons, R (2006), Organization and Analysis of Ground-Water Quality Data, Taylor & Francis Group, LLC.

Shewhart, W A (1939), Statistical Method from the Viewpoint of Quality Control, Harvard University Press.

Sinclair, P and Barret, C (2004), Lower Namoi Valley Groundwater Status Report 2004. Status for the Alluvial Groundwater Resources of the Lower Namoi Valley GMA001. NSW Department of Infrastructure, Planning and Natural Resources.

Skelt, K, Ife, D, Woolley, D, Evans, R and Hillier, J (2004), Murray-Darling Basin Groundwater Status 1990-2000 Catchment Report: Namoi River. Canberra, Murray-Darling Basin Commission.

SKM (2003), "Barwon Region Groundwater Flow System Literature Review". Sinclair Knight Merz.

Smithson, A (2009), "Lower Namoi Groundwater Source: Groundwater Management Area 001 Groundwater Status Report – 2008". NSW Department of Water and Energy, Sydney

The, C and Kelly, B (2009), 3D Analysis of Irrigation Bore Water Chemistry Data from the Namoi Catchment. Cotton Catchment Communities CRC, Summer Scholarship Final Report.

The, C (2008), "3D Spatial Analysis of Bore Hydrograph Data in the Lower Namoi Catchment". B.Sc Hons. Thesis, The University of New South Wales.

Timms, W and Berhane D (1999), Occurrence of Pesticides and Nitrate in Groundwater of the Liverpool Plains 1996-98, *Draft*. Department of Land and Water Conservation

Timms, W (1997), Liverpool Plains Water Quality Project - 1996/1997 Report on Groundwater Quality. Department of Land and Water Conservation.

Timms, W, Cunningham, I and Badenhop, A (2006), "Tamworth Effluent Reuse Scheme: Additional Monitoring Bores and Baseline Water Quality Monitoring". WRL Technical Report 2006/12.

Timms, W and Acworth, I (2006), "Aquifers and aquitards below the Liverpool Plains", In: Coal Mining and the Liverpool Plains, Plains Talk, Number 33, June 2006, Published by The Liverpool Plains Land Management Committee, pp 6-7.

Timms, W and Acworth, R I (2002), Induced leakage due to groundwater pumping and flood irrigation at the Pullaming Agricultural Field Station, Liverpool Plains. UNSW Water Research Laboratory, Research Report No. 208. http://www.wrl.unsw.edu.au.

Timms, W A, Cunningham, I L, Schwarz, M and Wasko, C (2008), "Hydrogeological investigation of the fate of salt mobilised under dryland cropping on the Cryon Plain, North Western NSW- Final Report". WRL Technical Report 2008/10. Interim Report to Department of Primary Industries (Agriculture) "National Action Plan Project – Mobilisation of 100 tons/ha of salt under dryland cropping".

Transfer Standard July 1999, National Groundwater Committee Working Group on National Groundwater Data Standards.

USEPA (1989), Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Interim Final Guidance, EPA/530-SW-89-026; U.S. EPA; Office of Solid Waste Management, Washington, D.C.

USEPA (2006), Data Quality Assessment: A Reviewer's Guide, EPA/240/B-06/002, U.S. EPA; Office of Solid Waste Management, Washington, D.C.

USEPA (2006), Data Quality Assessment: Statistical Methods for Practitioners, EPA/240/B-06/003, U.S. EPA; Office of Solid Waste Management, Washington, D.C.

USGS (2001), Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data. US Geological Survey, Circular 1217.

Waite, T D, Jankowksi J and Acworth R I (1995), Groundwater chemistry, distribution of salts and flow regimes in the Coxs Creek catchment, Liverpool Plains. UNSW Report to LWRRDC Project UNS16.

Winter, T C, Harvey, J W, Franke, O L and Alley, W M (1998), Ground Water and Surface Water: A Single Resource. Geological Survey (USGS).

WRL

Report No. 2009/25

NAMOI CATCHMENT

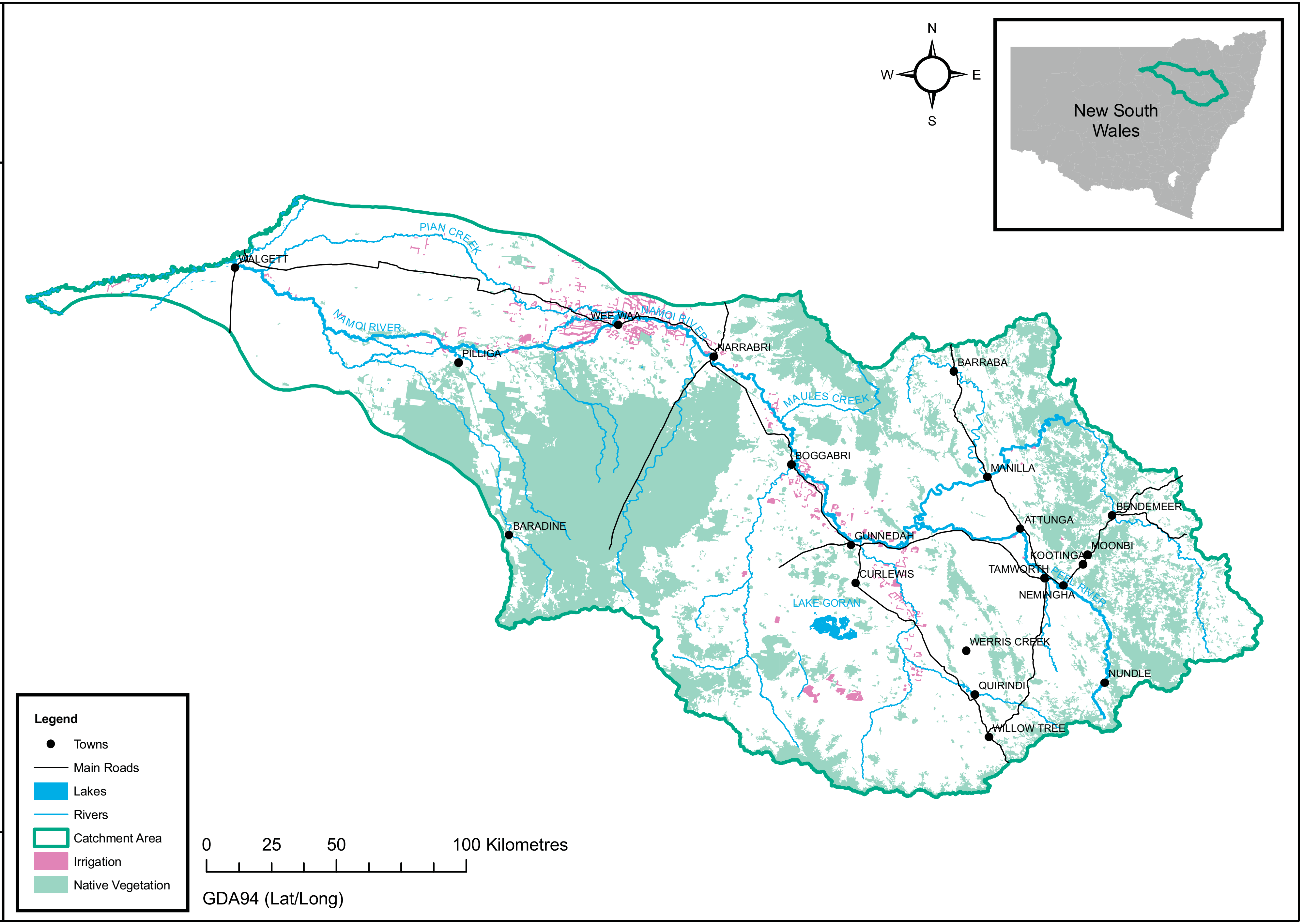


Figure 1

Namoi_1_1_Fig1.mxd

WRL

Report No. 2009/25

GROWER SAMPLE SITES

N

W E

S

0 10 20 40 Kilometres

GDA94 (Lat/Long)

Legend

- Grower Sample Sites
- Towns
- Major Rivers
- Major Roads
- Catchment Area
- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

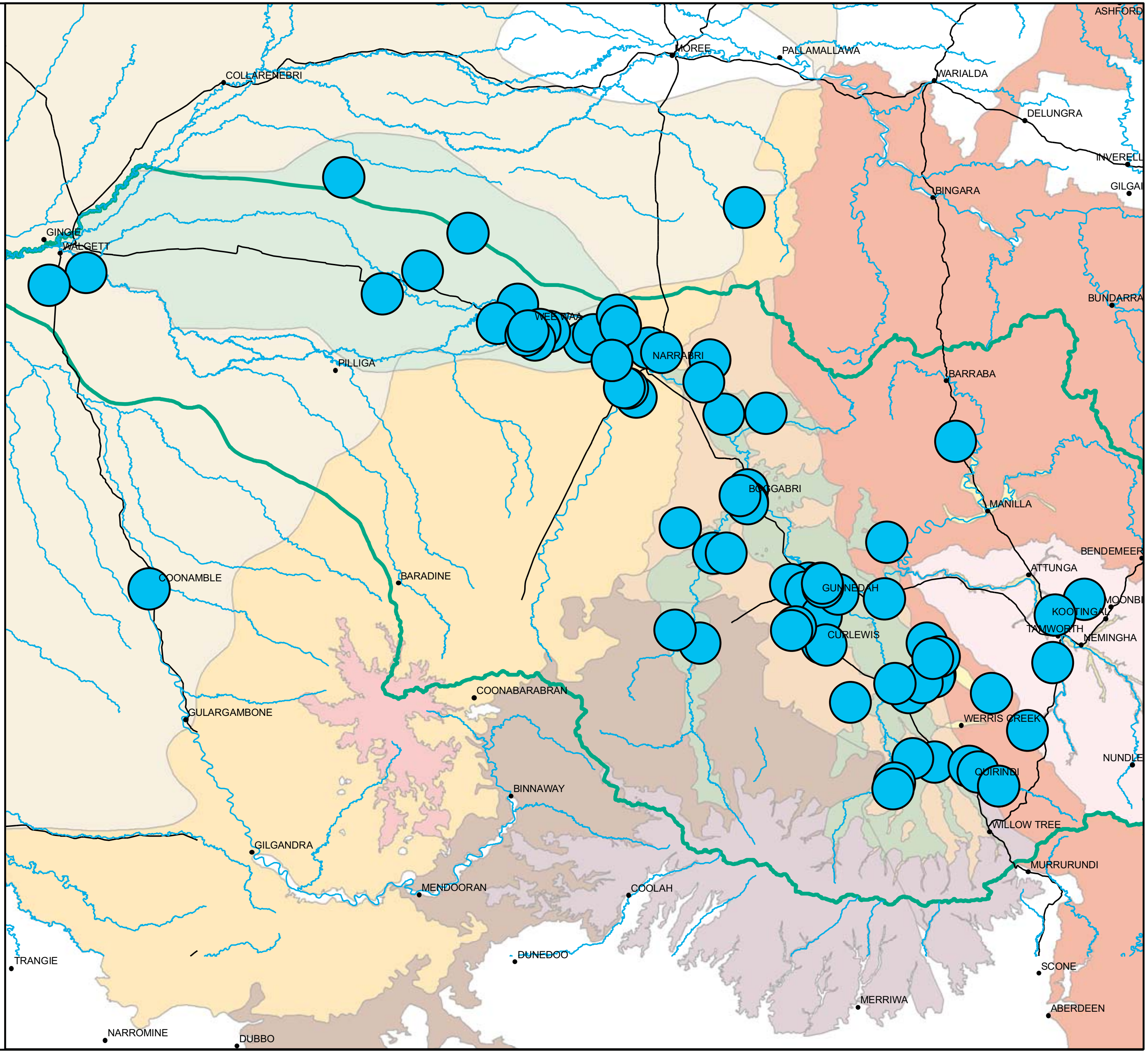


Figure 2

Namoi_3_8.mxd

WRL

Report No. 2009/25

SALINITY ACROSS GROWER SITES

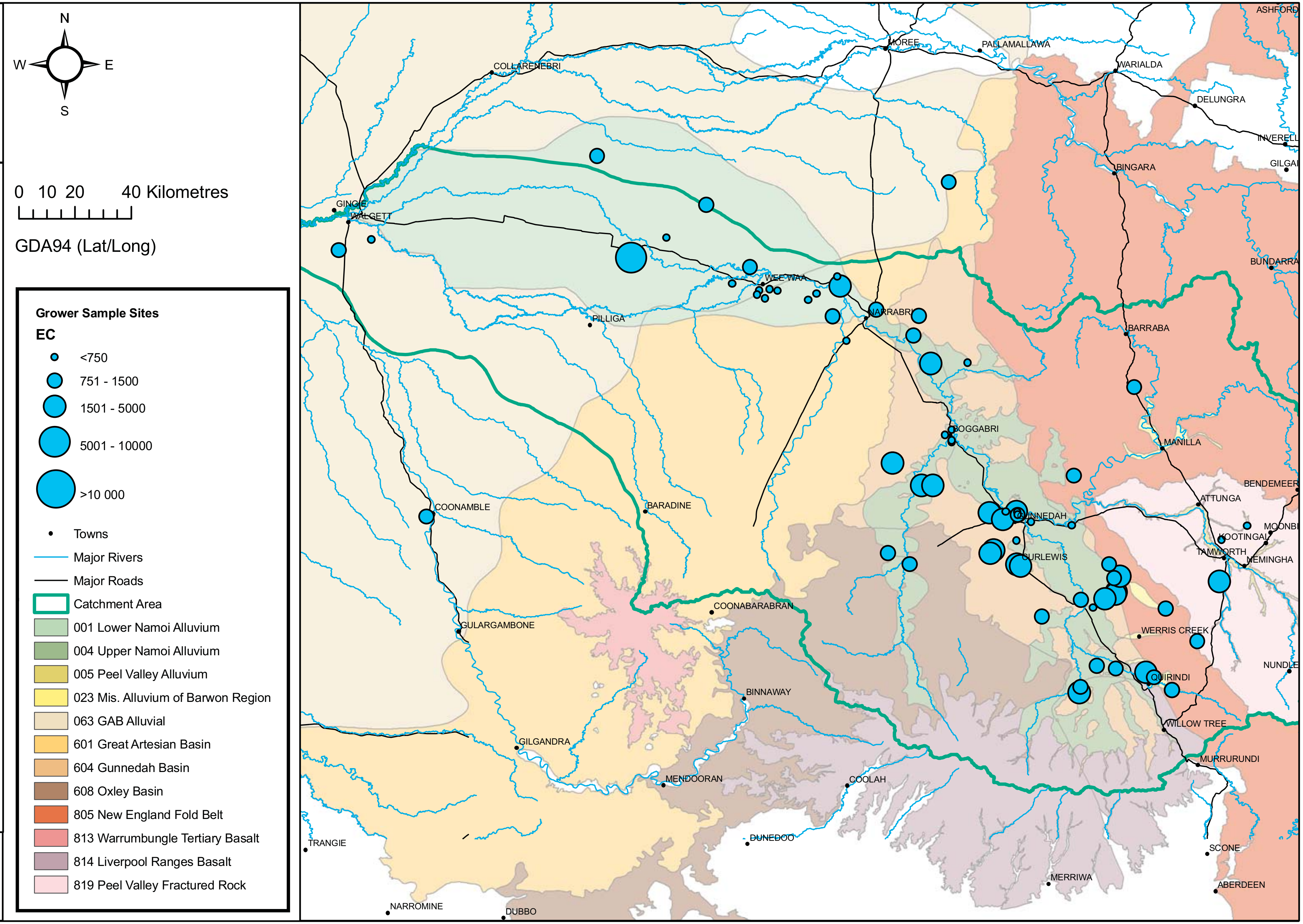
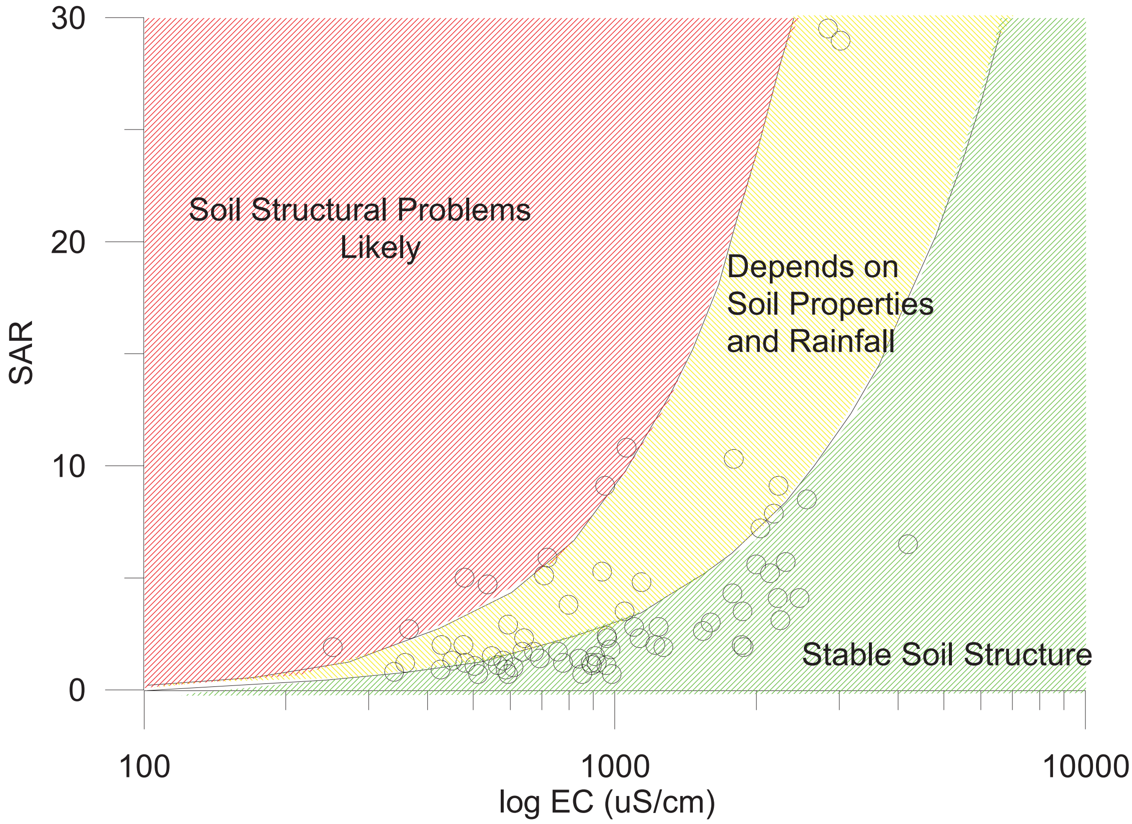


Figure 3

Namoi_3_8.mxd



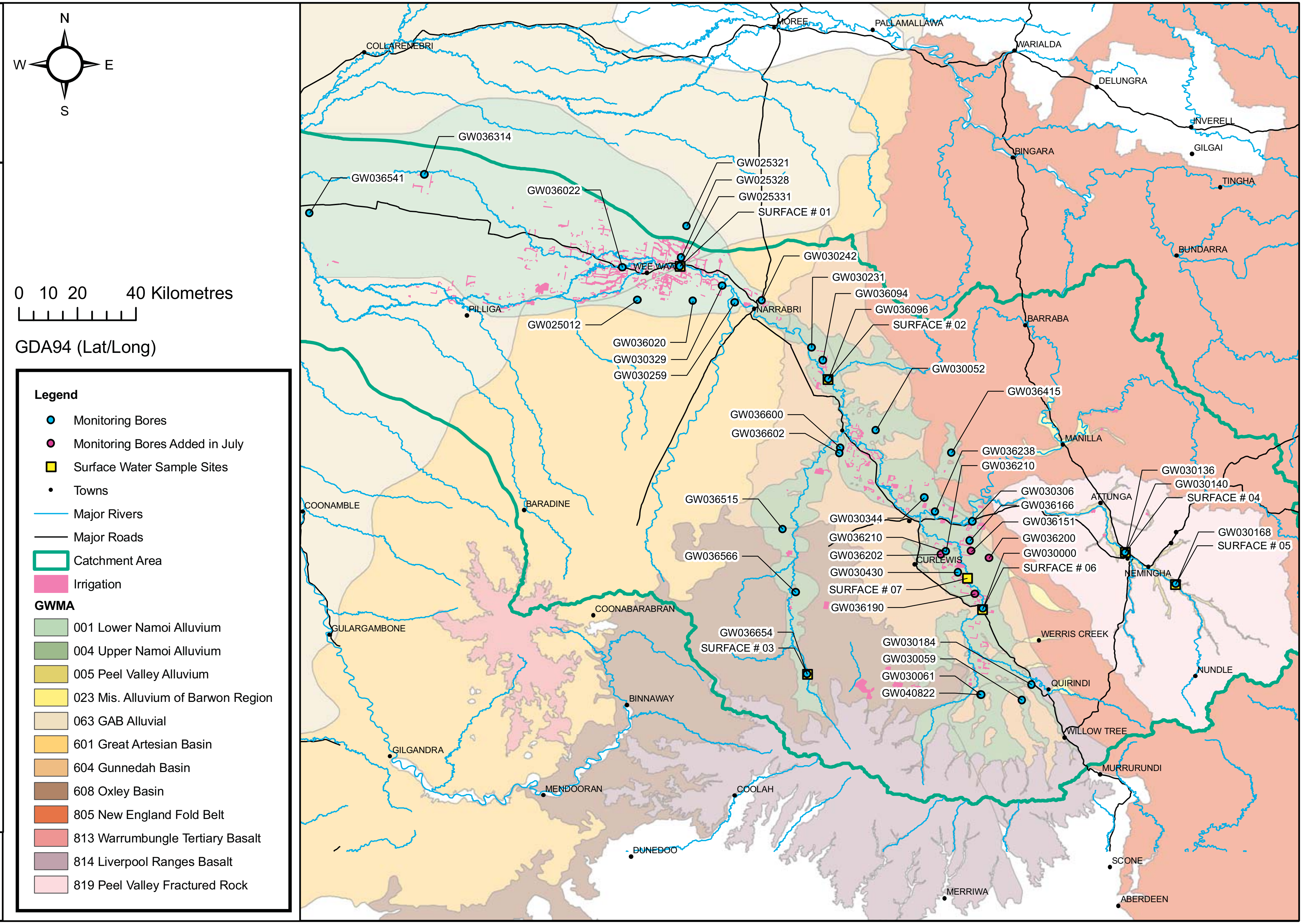
WRL Report No. 2009/25	SAR-EC GROWERS SAMPLES	Figure 4

WRL Report No. 2009/25

TARGET GROUNDWATER MONITORING BORES

Figure 5

Namoi_3_6.mxd



WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 1
UPPER MONITORING UNIT

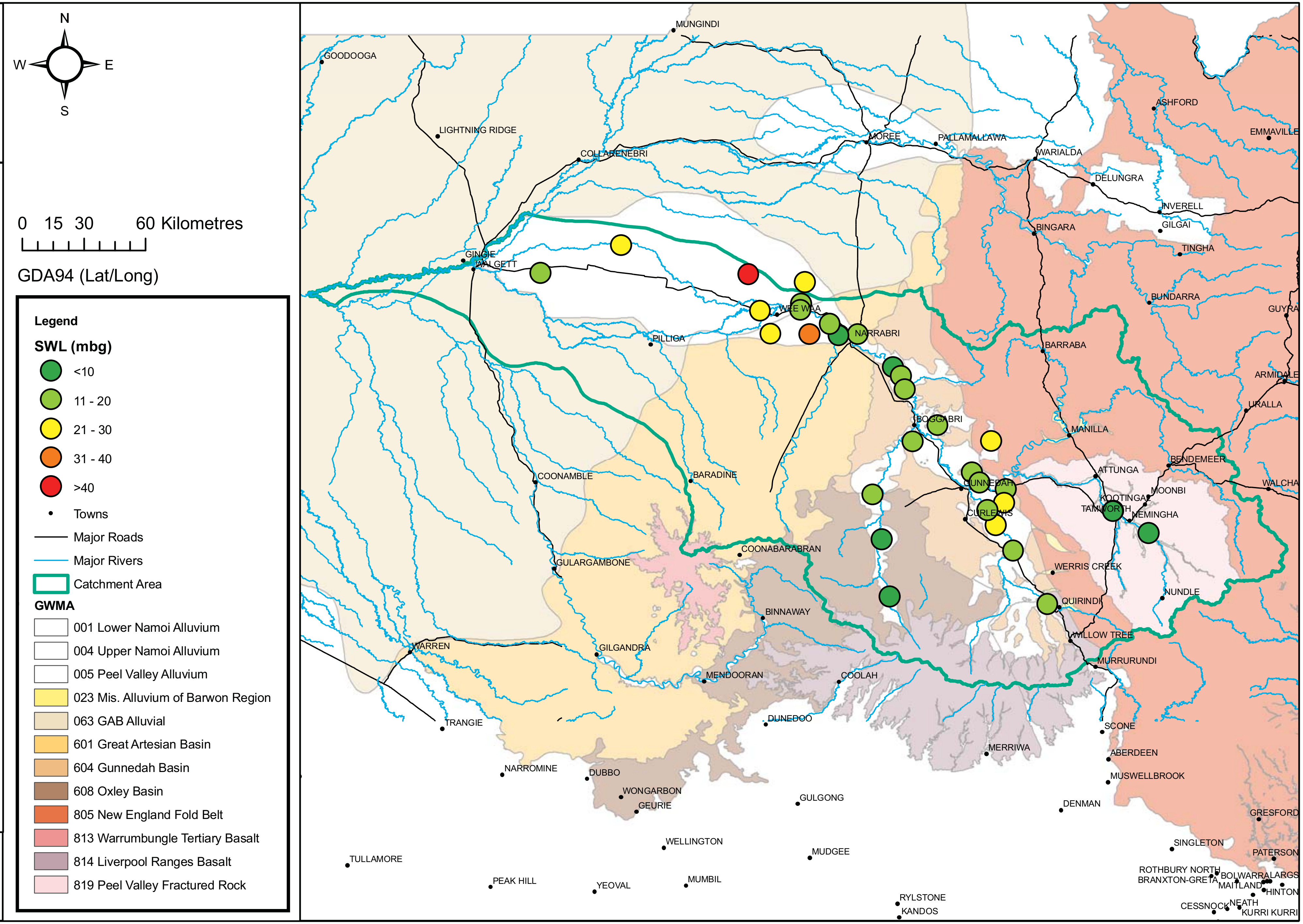
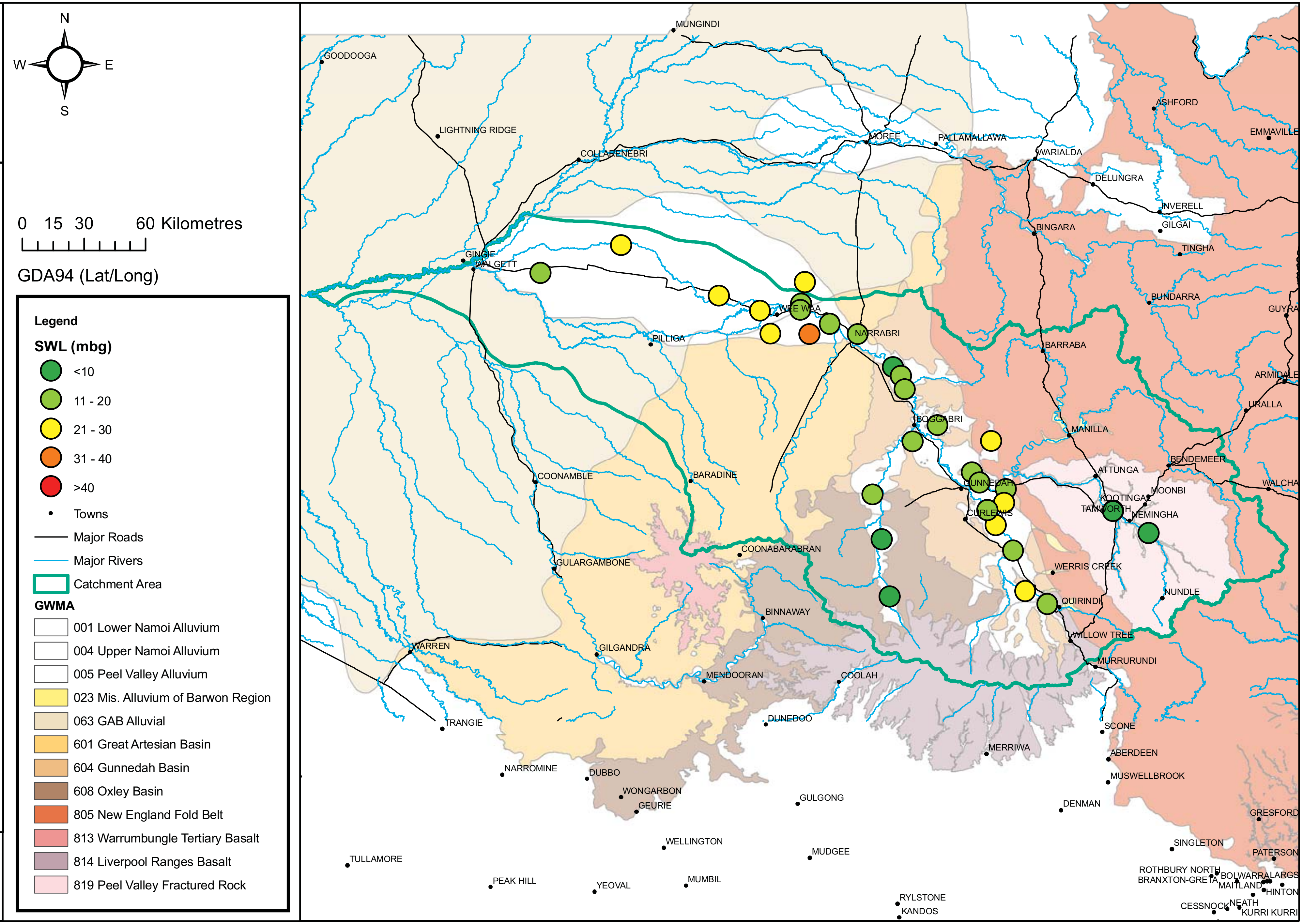


Figure
6

Namoi_6_7.mxd

WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 2
UPPER MONITORING UNIT



Namoi_6_8.mxd

Figure 7

WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 3
UPPER MONITORING UNIT

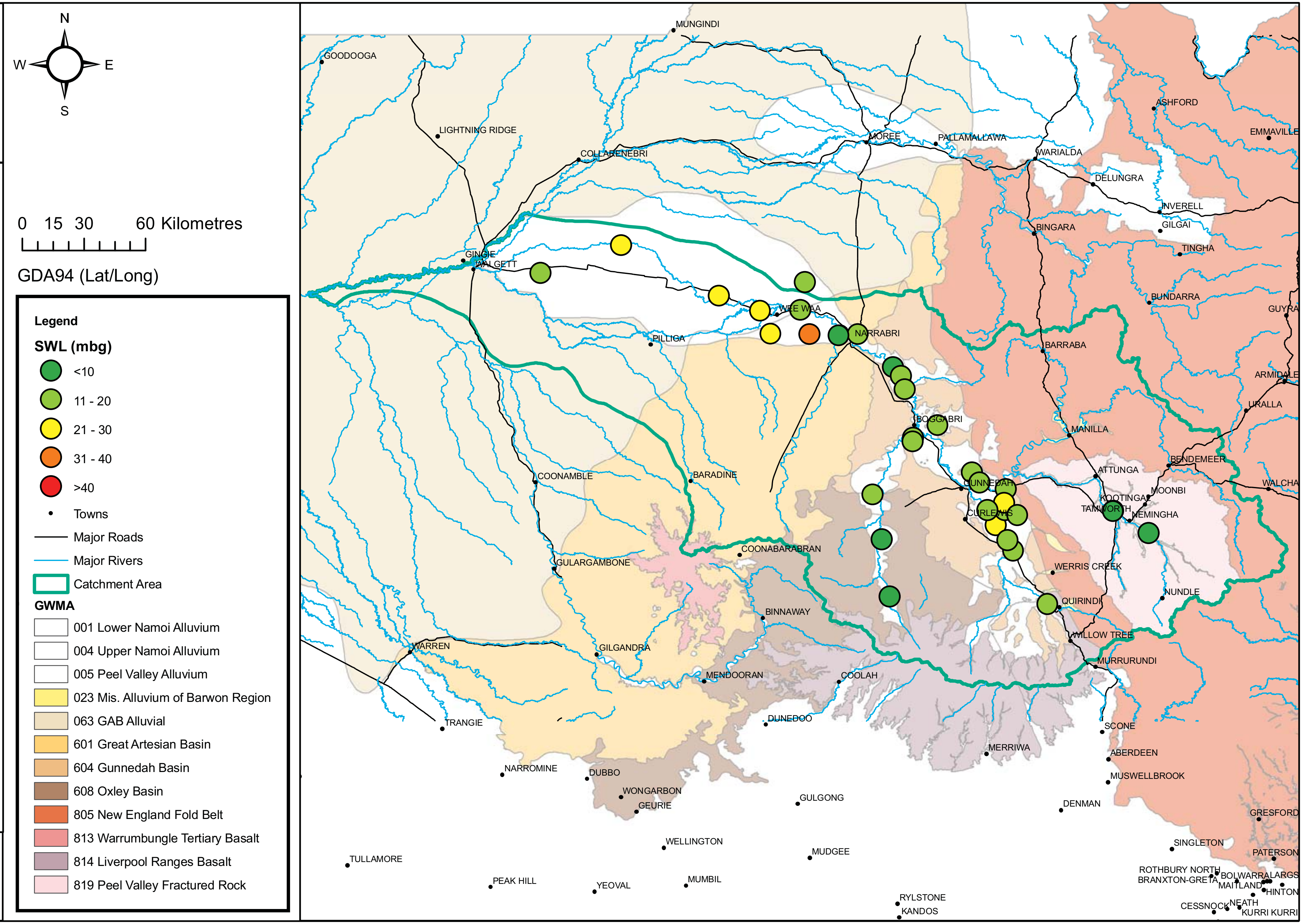


Figure
8

Namoi_6_9.mxd

WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 1
LOWER MONITORING UNIT

Figure 9

Namoi_6_10.mxd

N
W E
S

0 15 30 60 Kilometres

GDA94 (Lat/Long)

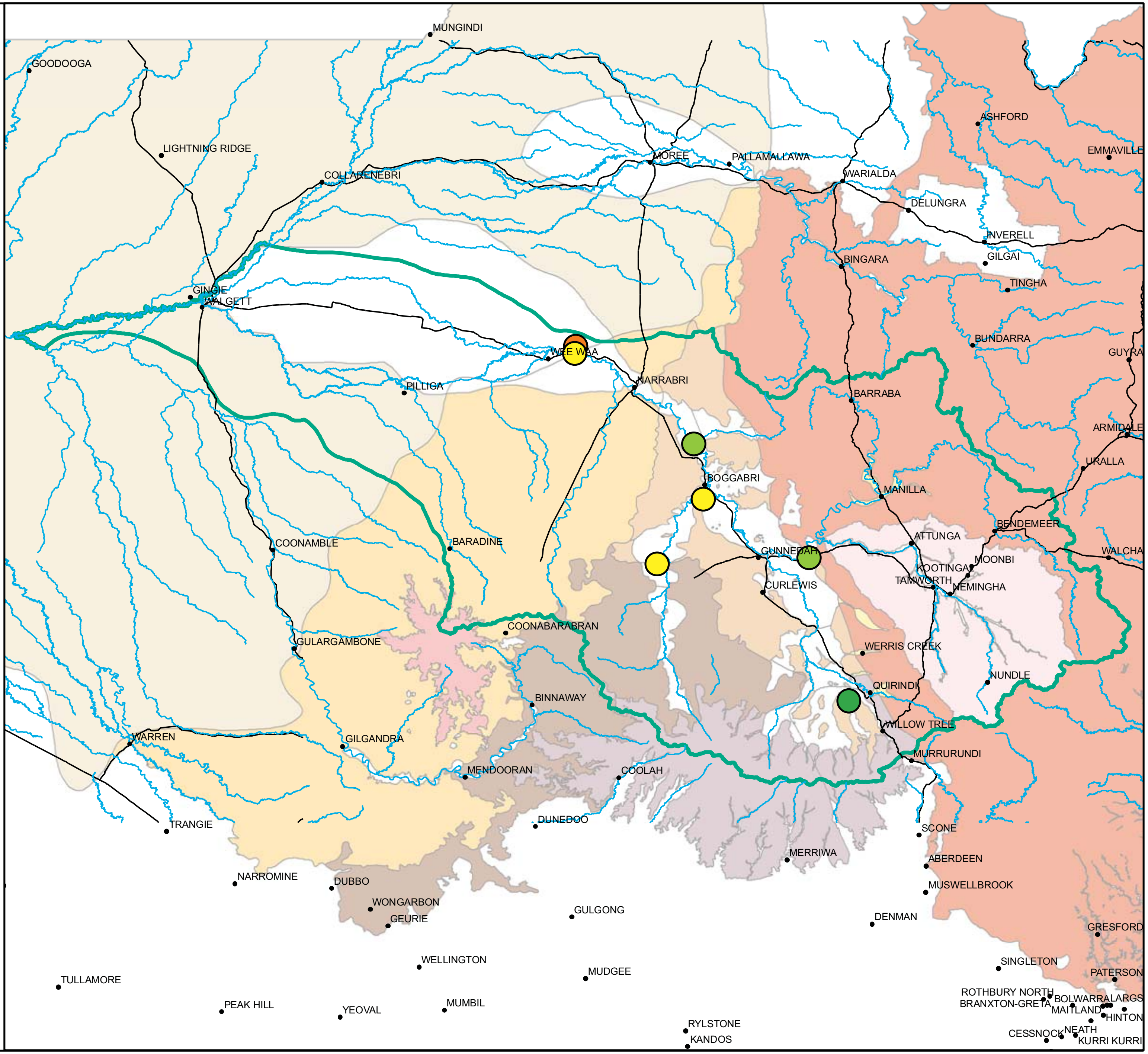
Legend

SWL (mbg)

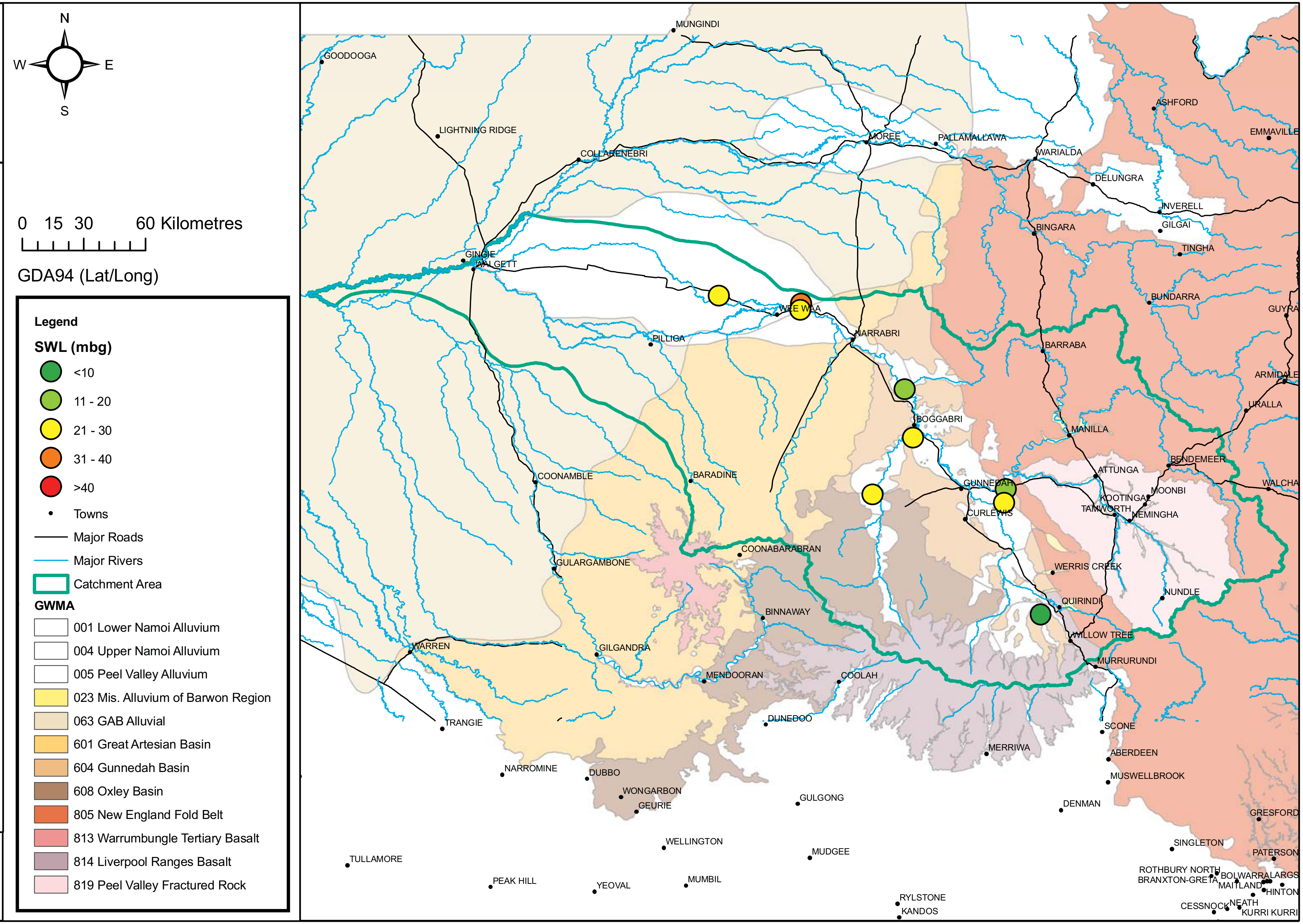
- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



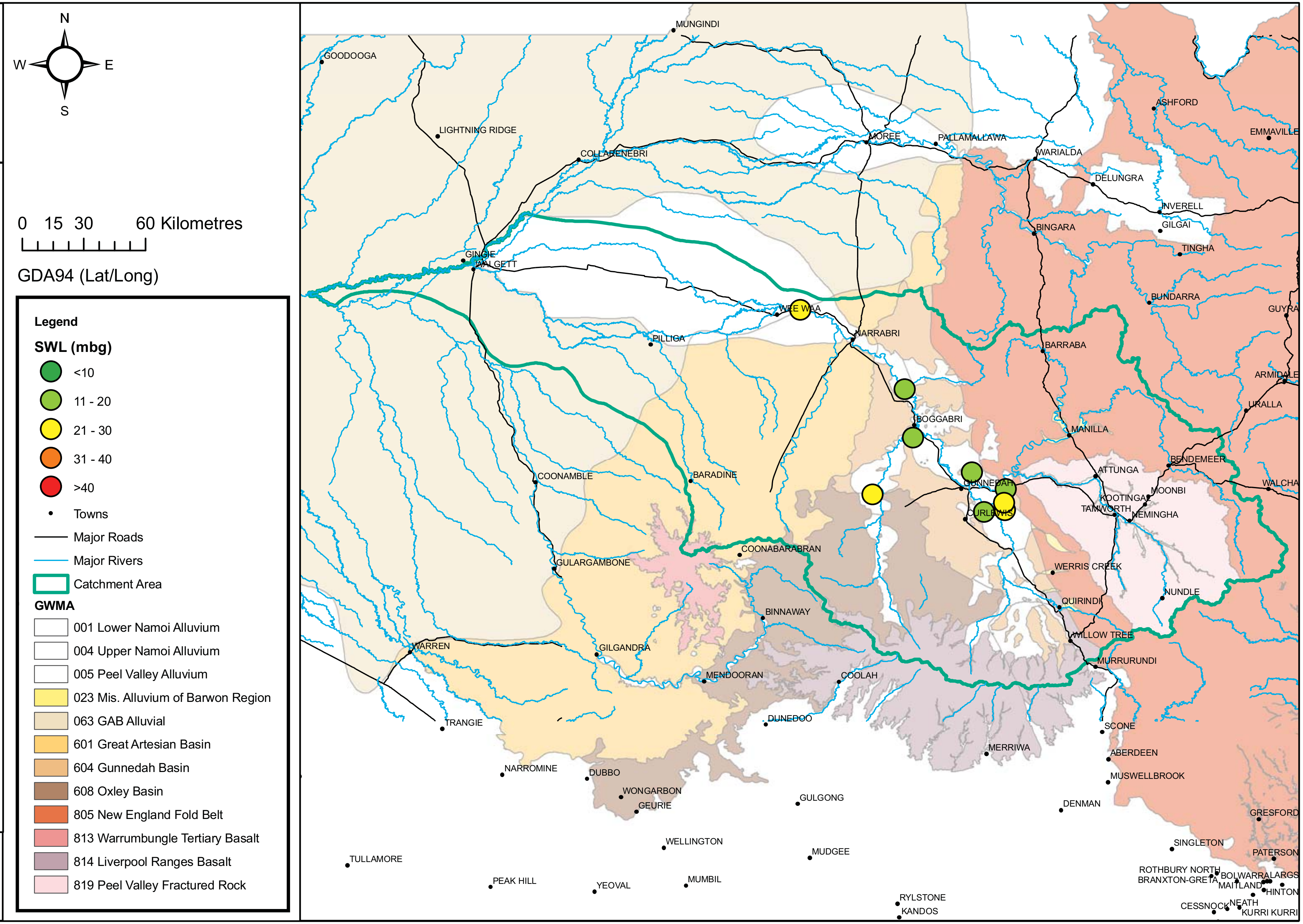
WRL
Report No. 2009/25



SWL (mbg) - WRL MONITORING ROUND 2
LOWER MONITORING UNIT

Figure
10

Namoi_6_11.mxd



WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 3
LOWER MONITORING UNIT

Figure
11

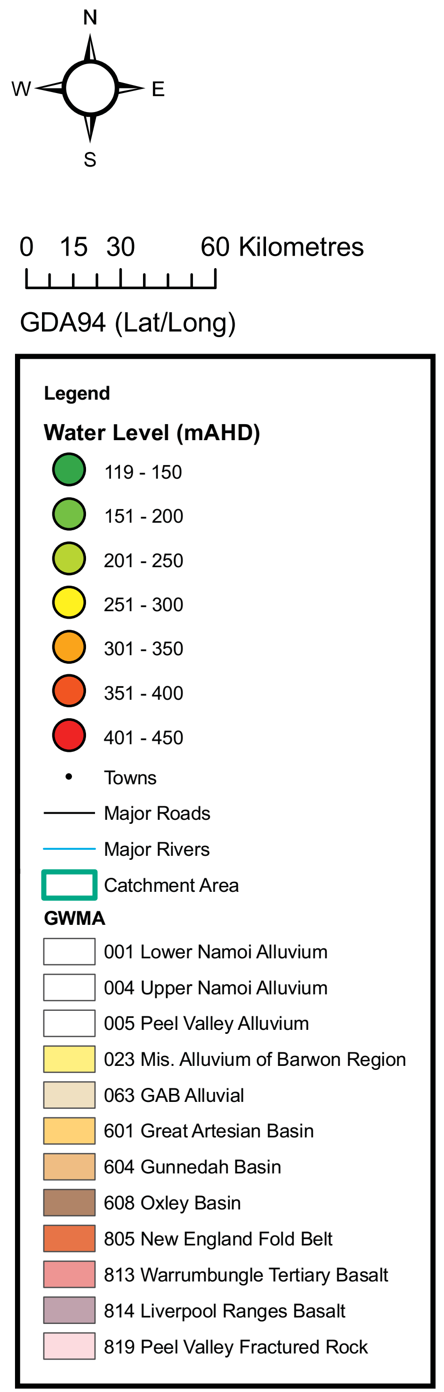
Namoi_6_12.mxd

WRL

Report No. 2009/25

GROUNDWATER LEVELS (mAHD) - WRL MONITORING ROUND 1

UPPER MONITORING UNIT



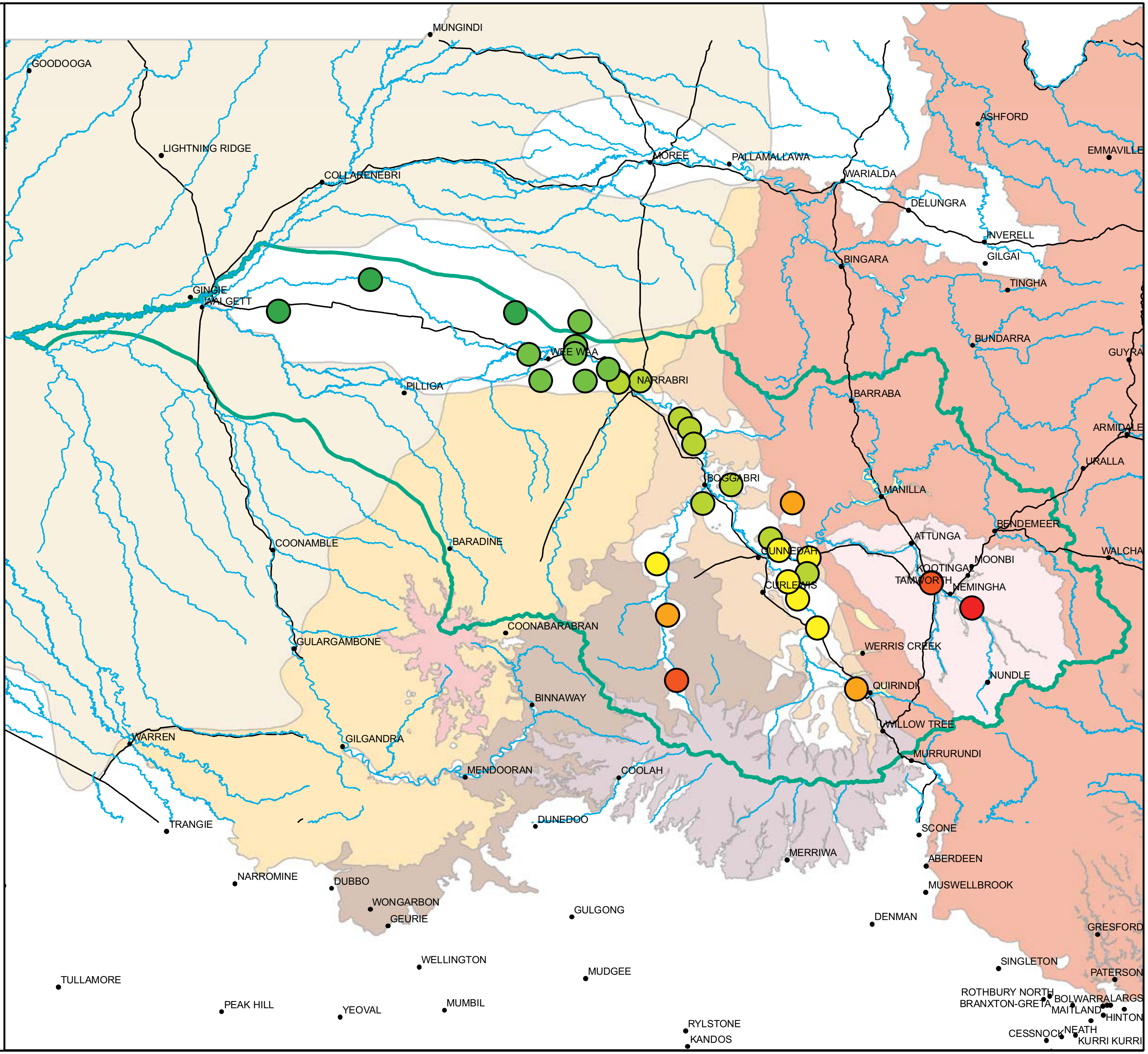
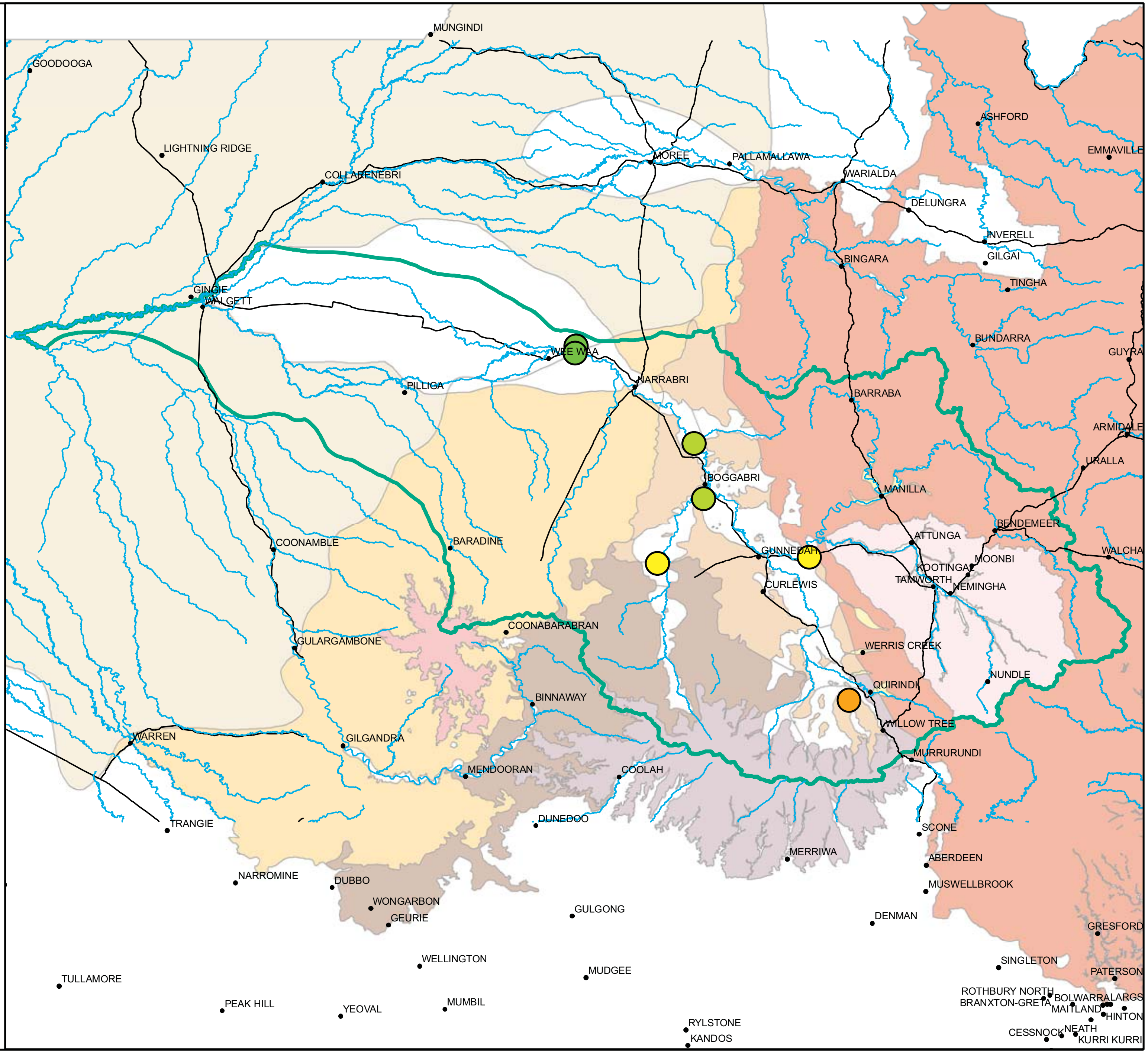


Figure 12

Namoi_6_13.mxd



N
W E
S

0 15 30 60 Kilometres

GDA94 (Lat/Long)

Legend

Water Level (mAHD)

- 119 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

WRL
Report No. 2009/25

GROUNDWATER LEVELS (mAHD) - WRL MONITORING ROUND 1
LOWER MONITORING UNIT

Figure
13

Namoi_6_14.mxd

WRL
Report No. 2009/25

SALINITY - WRL MONITORING ROUND 1
UPPER MONITORING UNIT

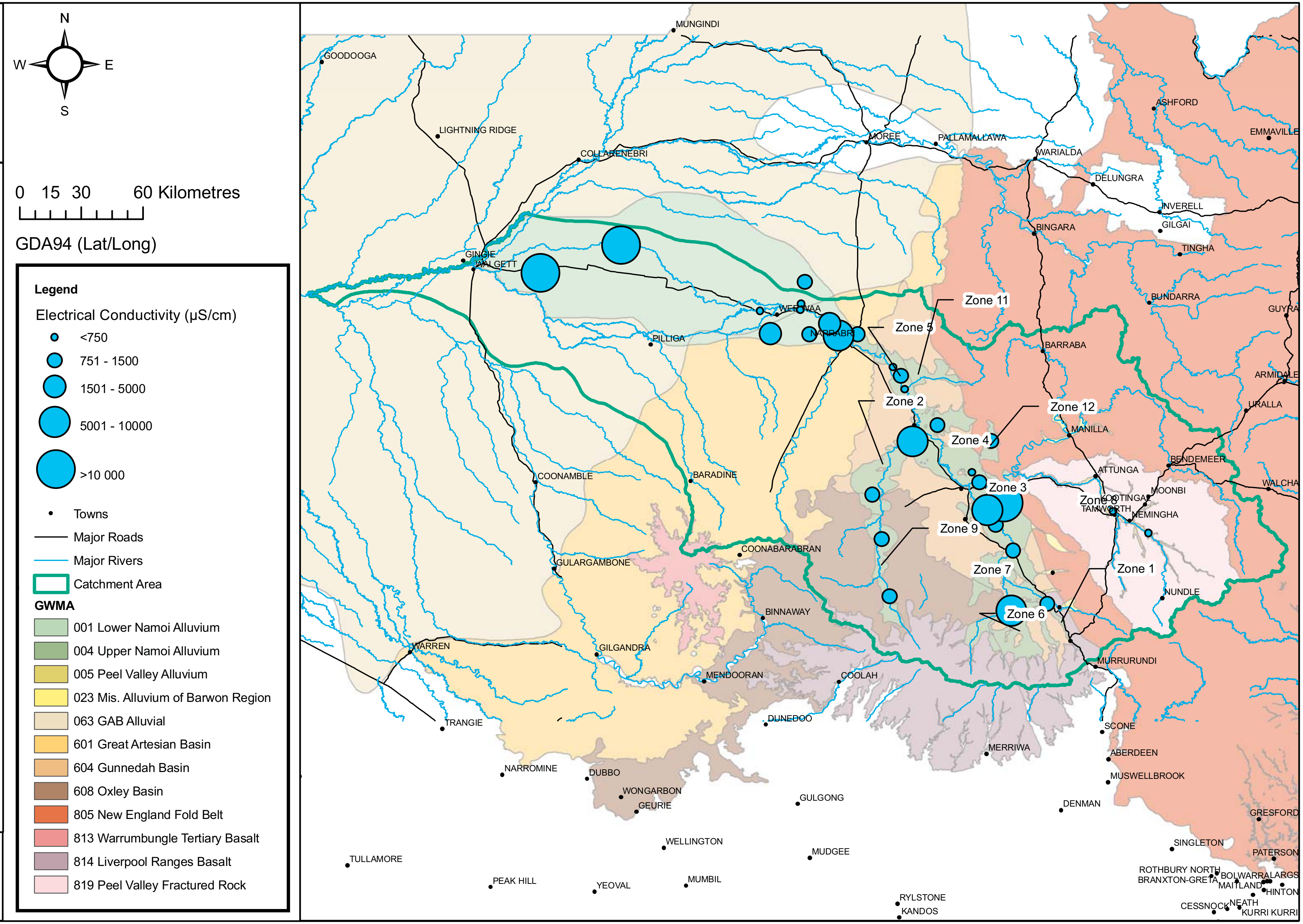
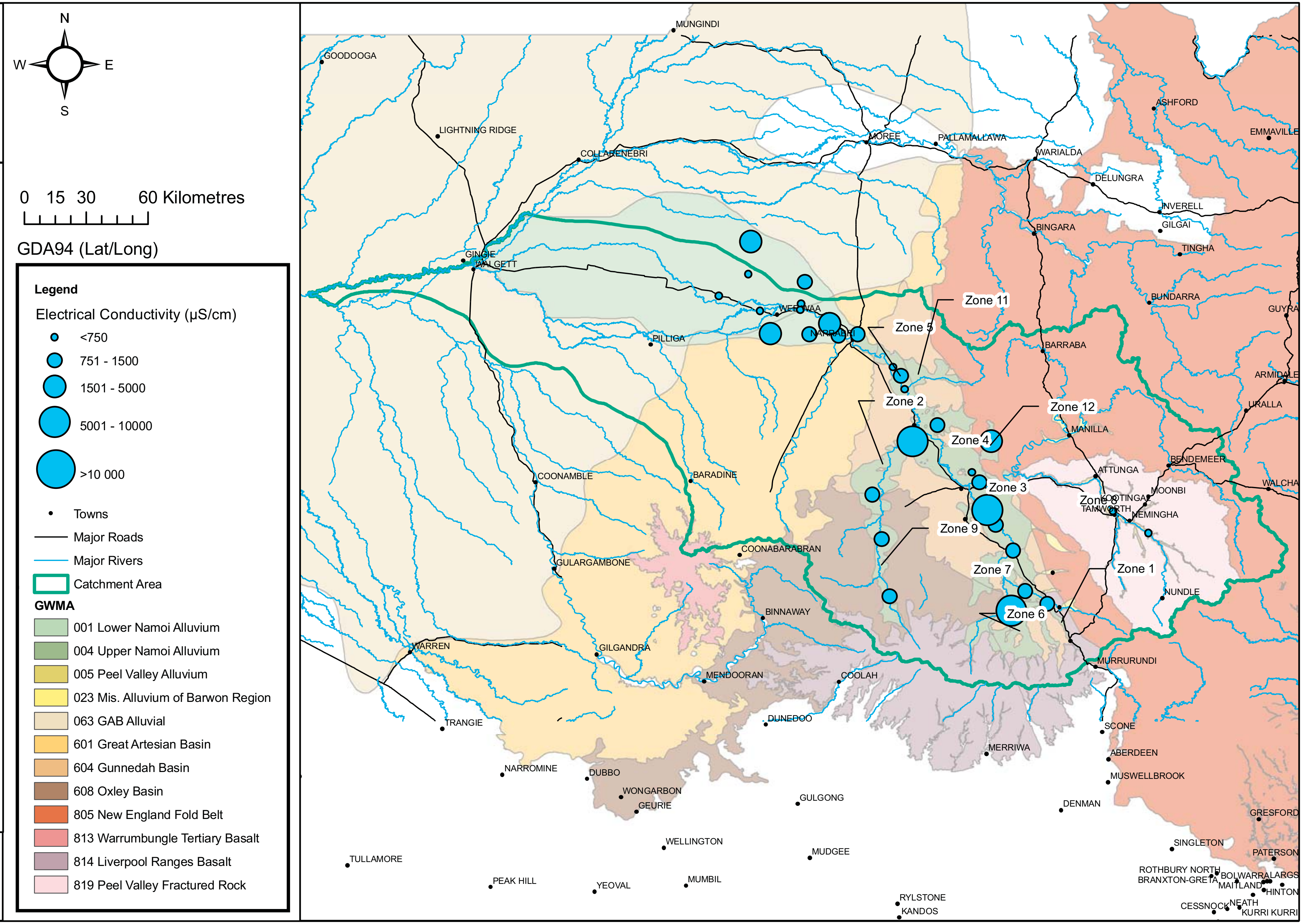


Figure
14

Namoi_6_1.mxd

WRL
Report No. 2009/25



SALINITY - WRL MONITORING ROUND 2
UPPER MONITORING UNIT

Figure
15

Namoi_6_2.mxd

WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 3

UPPER MONITORING UNIT

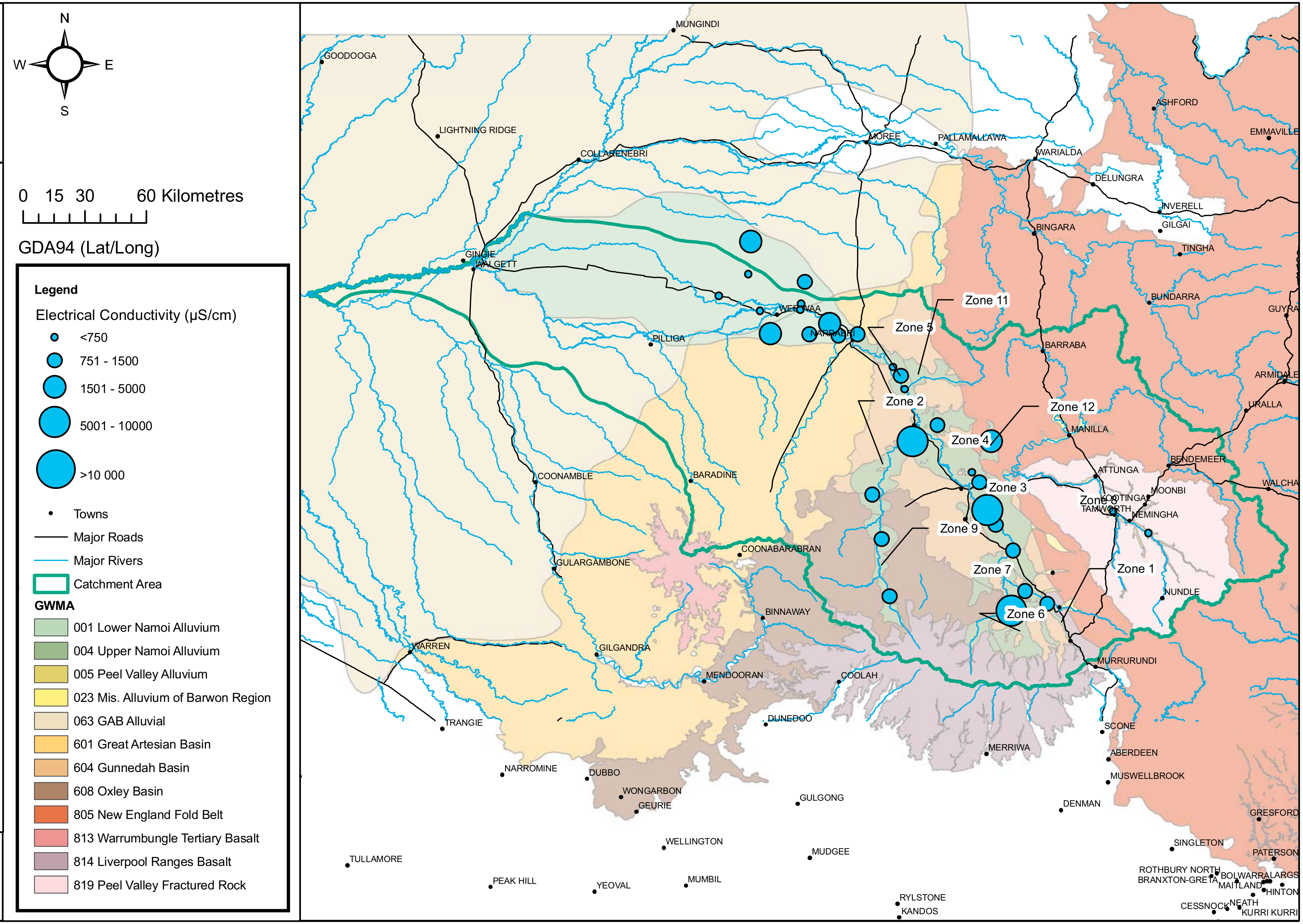


Figure 16

Namoi_6_3.mxd

WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 1
LOWER MONITORING UNIT

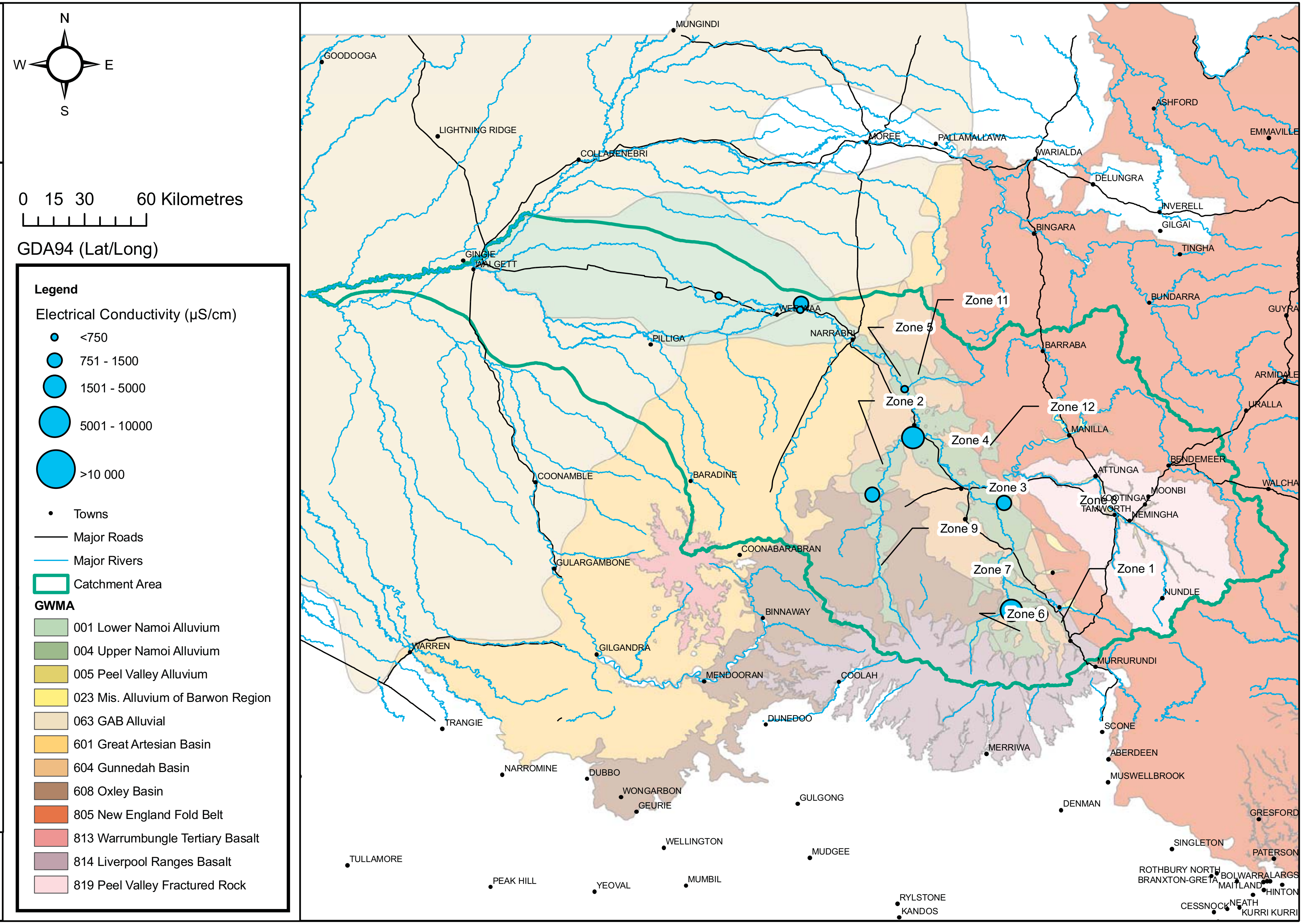
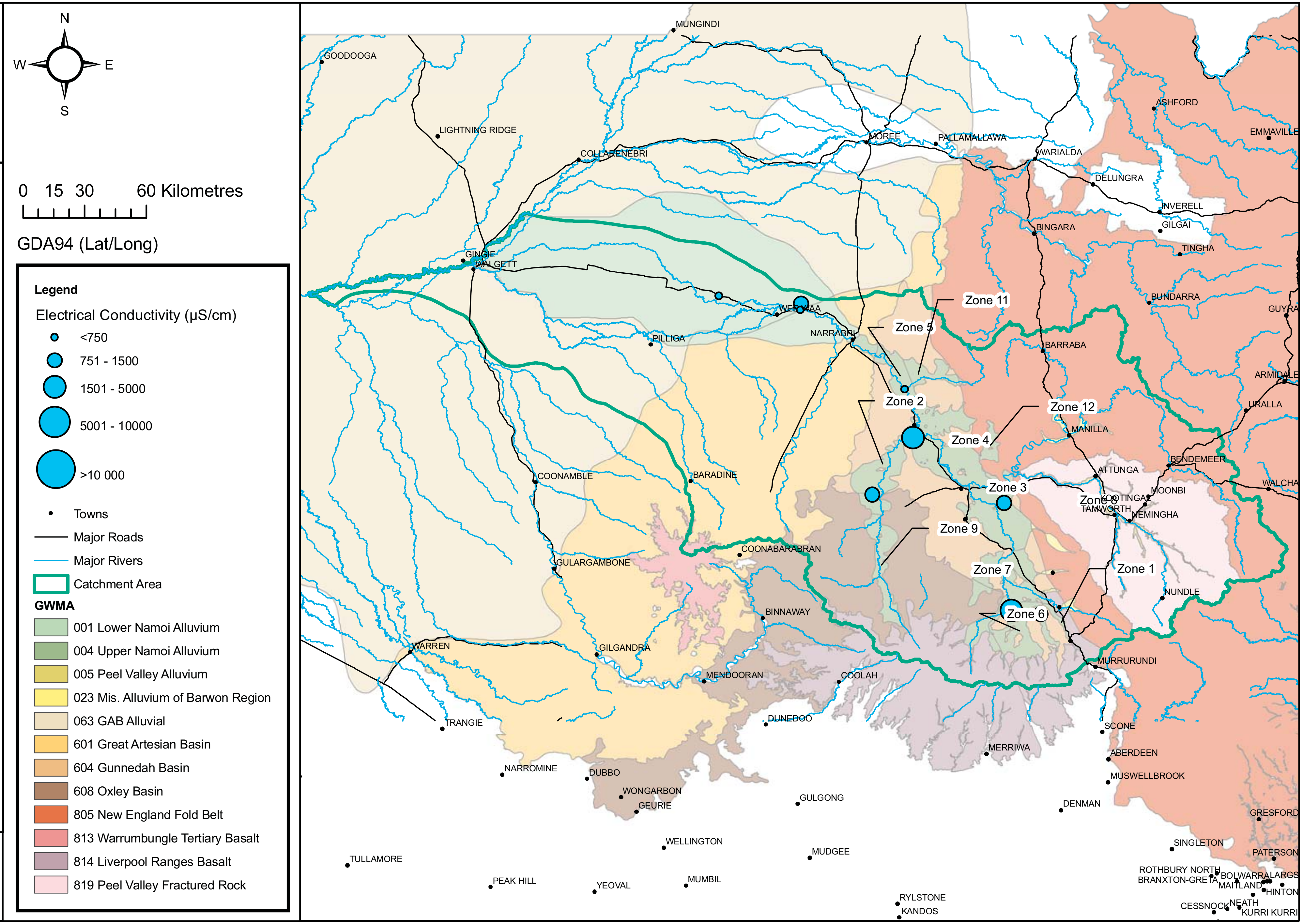


Figure 17

Namoi_6_4.mxd

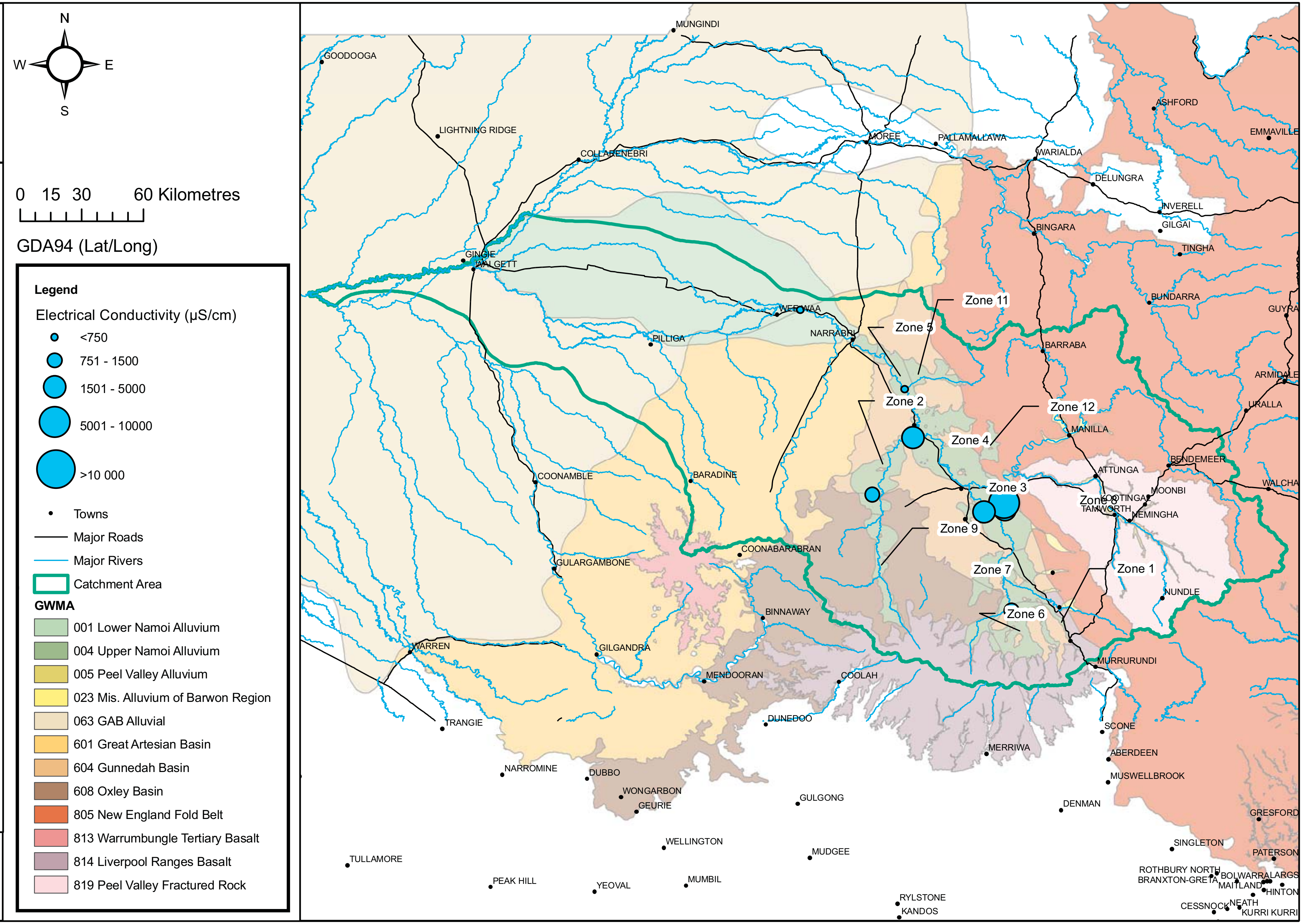


WRL
Report No. 2009/25

SALINITY - WRL MONITORING ROUND 2
LOWER MONITORING UNIT

Figure
18

Namoi_6_5.mxd

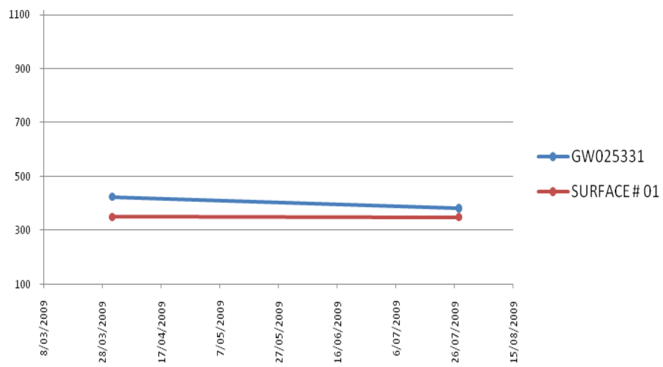


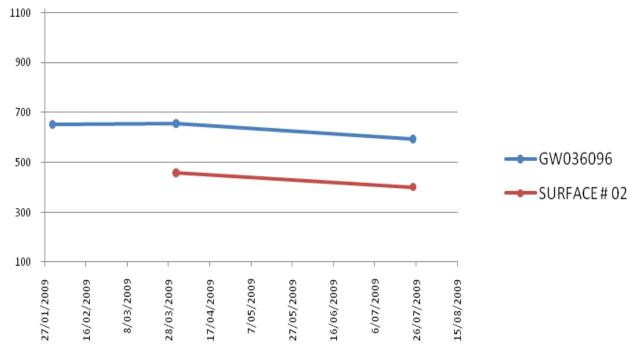
WRL
Report No. 2009/25

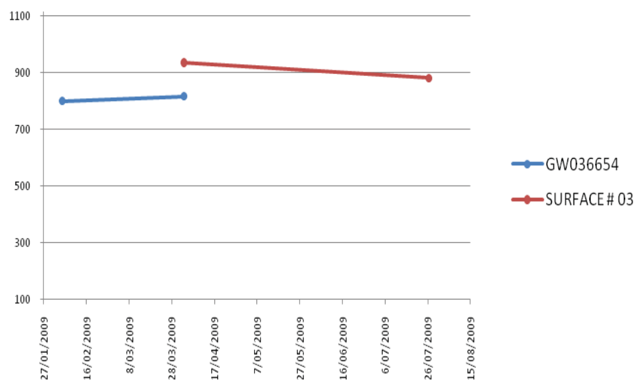
SALINITY - WRL MONITORING ROUND 3
LOWER MONITORING UNIT

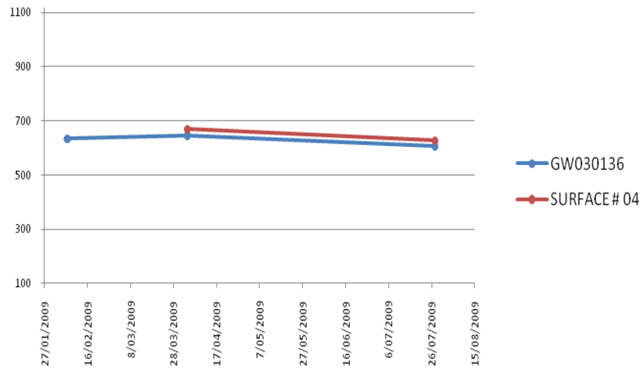
Figure
19

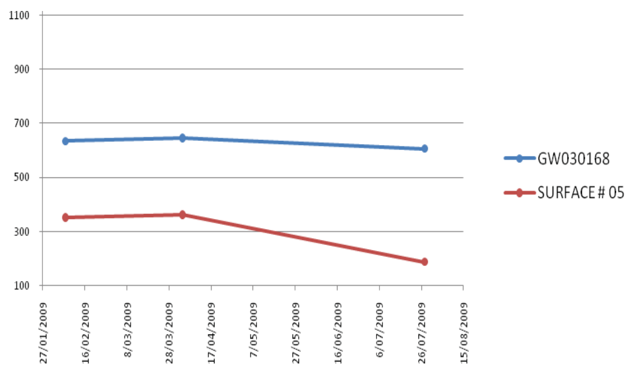
Namoi_6_6.mxd

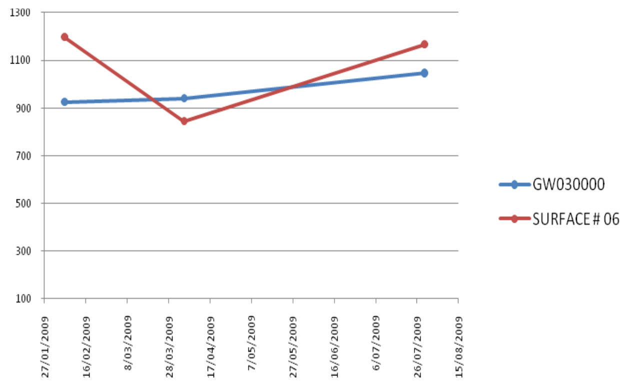


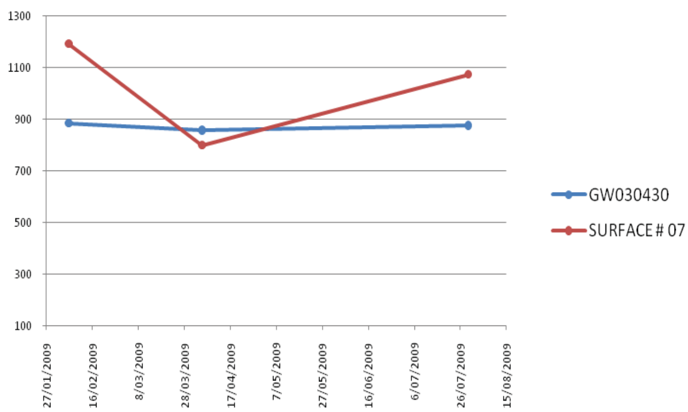




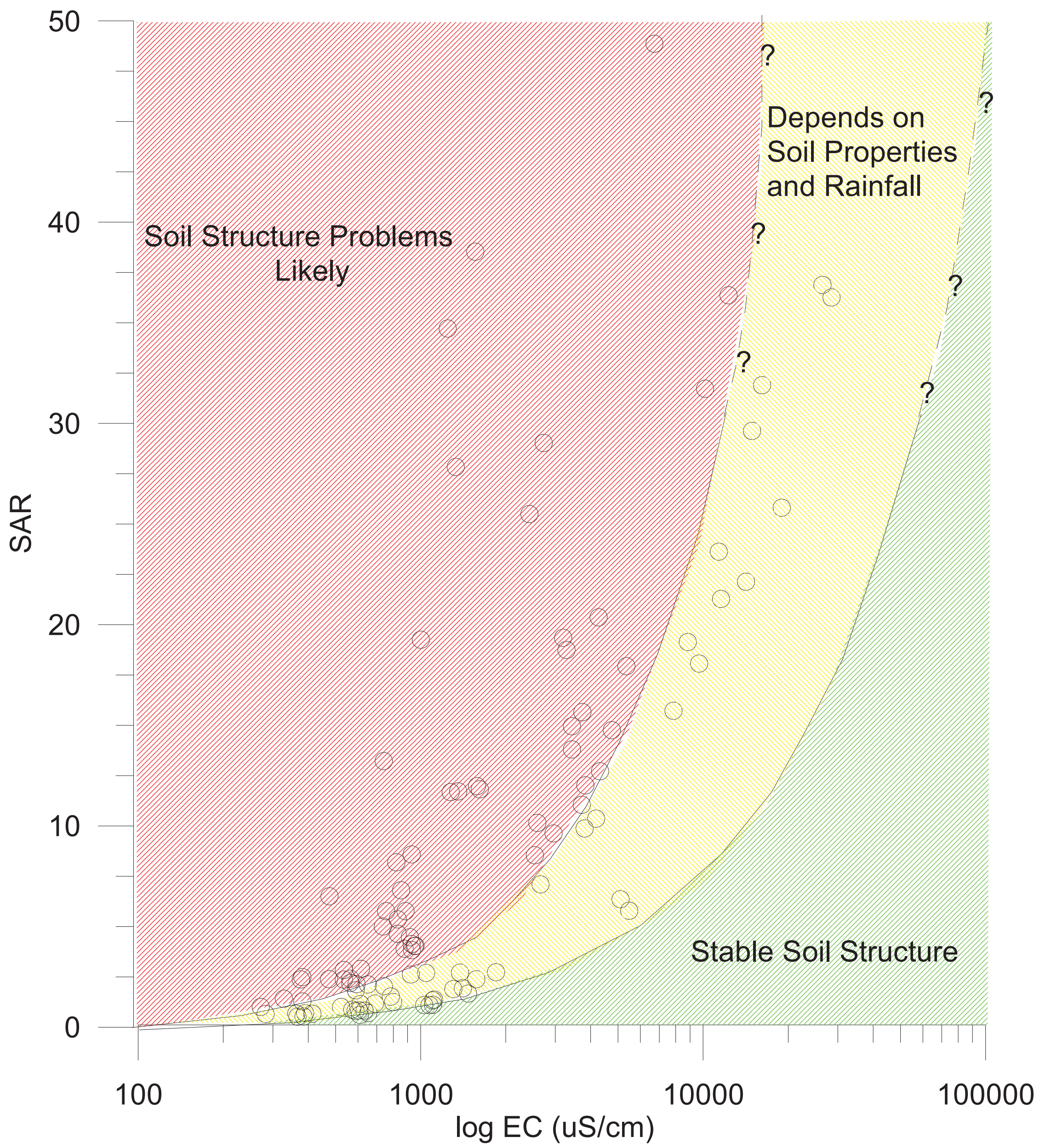




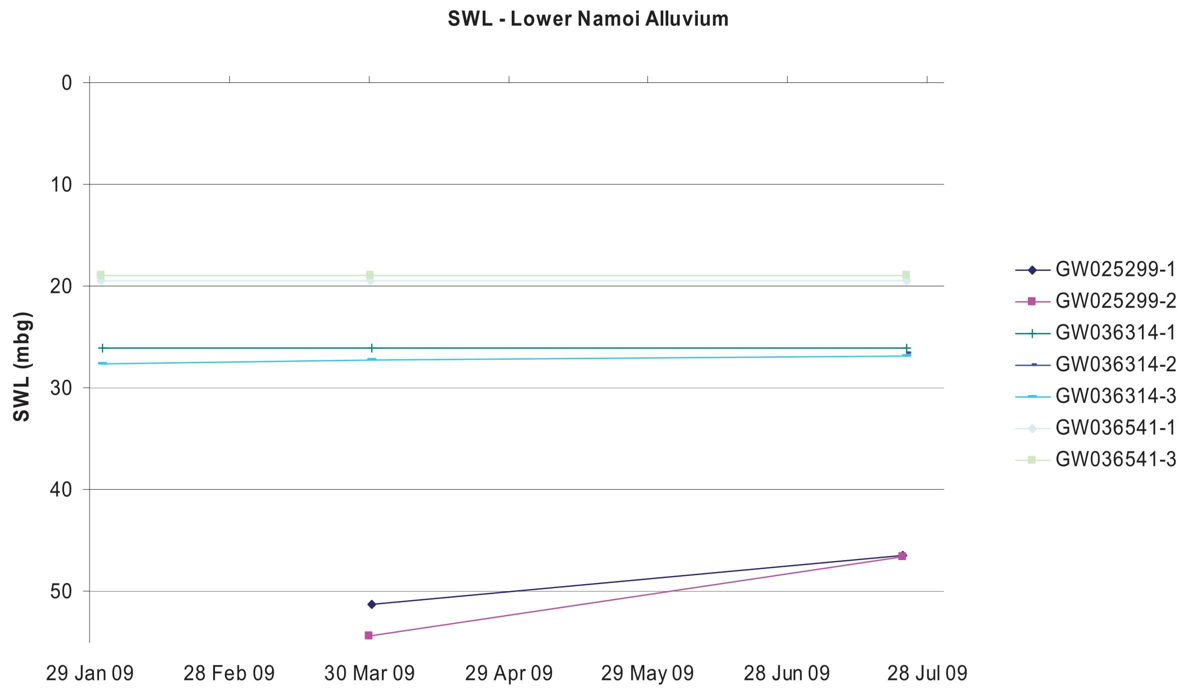


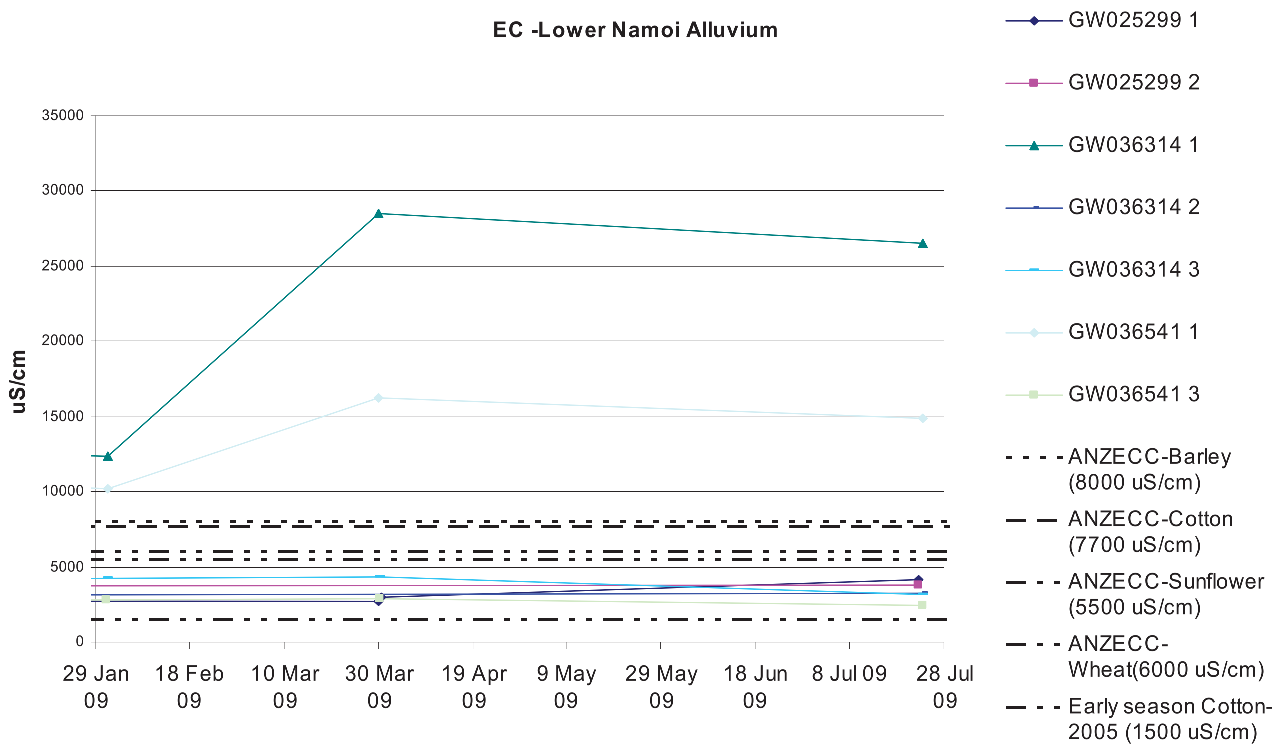


WRL Report No. 2009/25	SALINITY COMPARISON BETWEEN SURFACE WATER SITES AND NEIGHBOURING MONITORING BORES	Figure 20

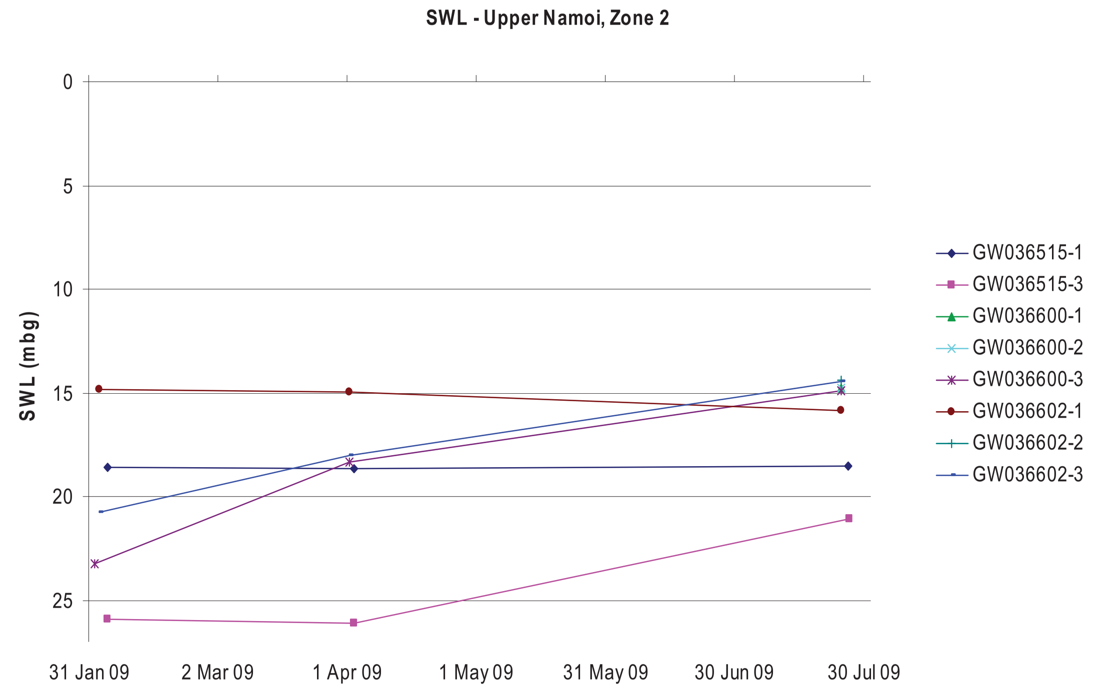


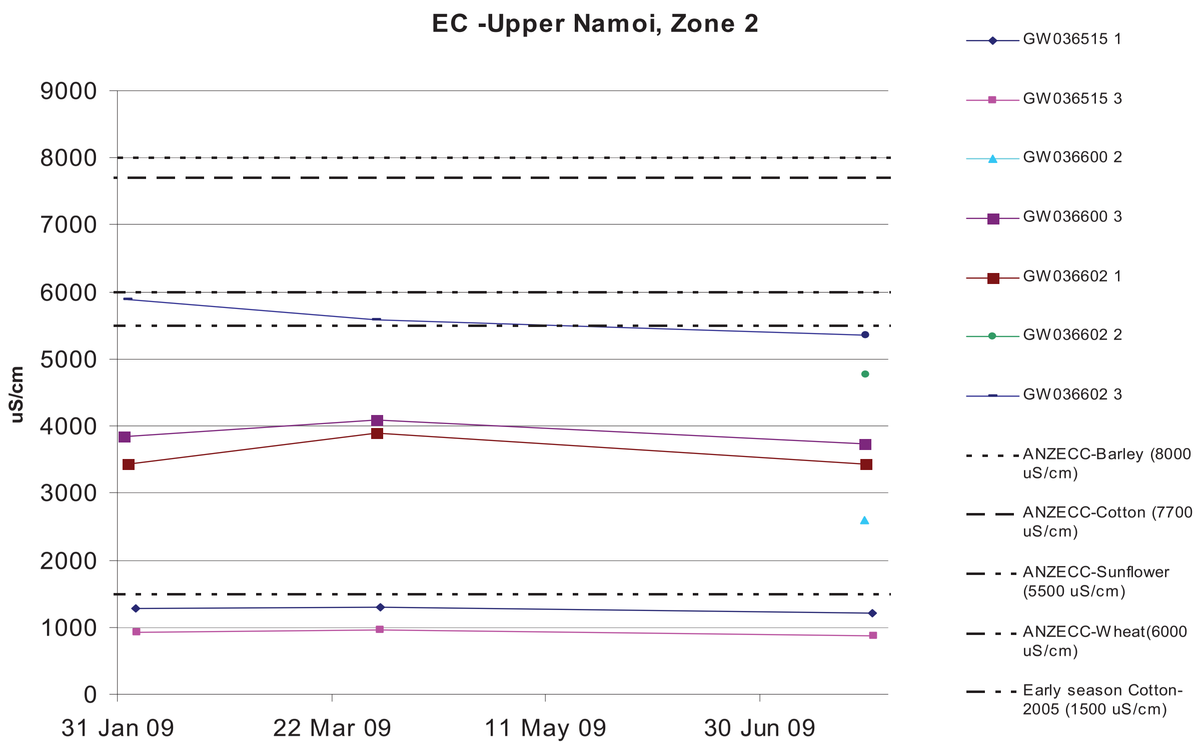
WRL Report No. 2009/25	SAR-EC WRL MONITORING 2009	Figure 21





WRL Report No. 2009/25	SWL & EC, WRL MONITORING 2009 LOWER NAMOI ALLUVIUM	Figure 22

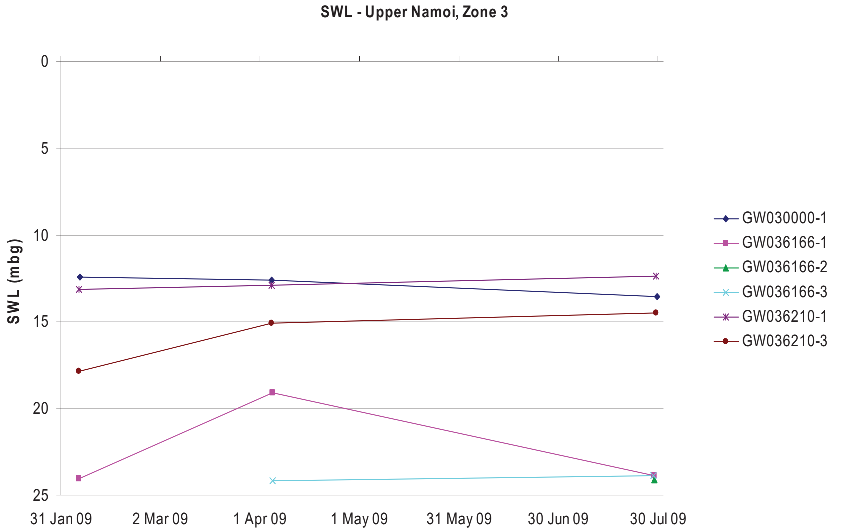


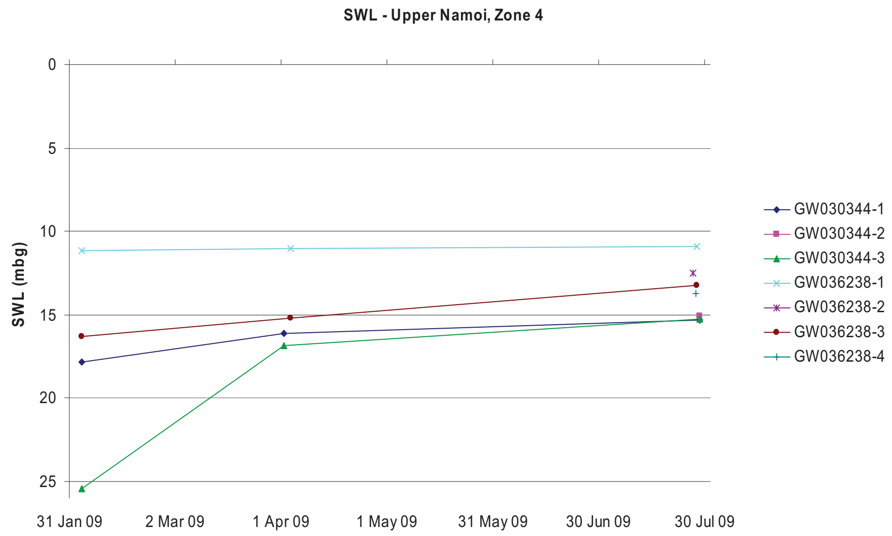


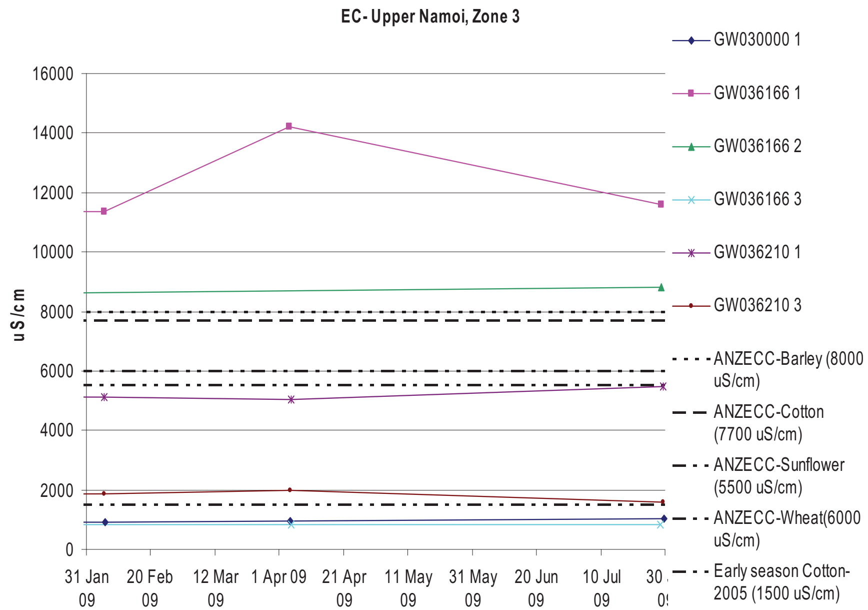
WRL Report No. 2009/25	SWL & EC, WRL MONITORING 2009 UPPER NAMOI ALLUVIUM, ZONE 2	Figure 23

WRL
Report No. 2009/25

SWL & EC, WRL MONITORING 2009
UPPER NAMOI ALLUVIUM, ZONE 3 & ZONE 4







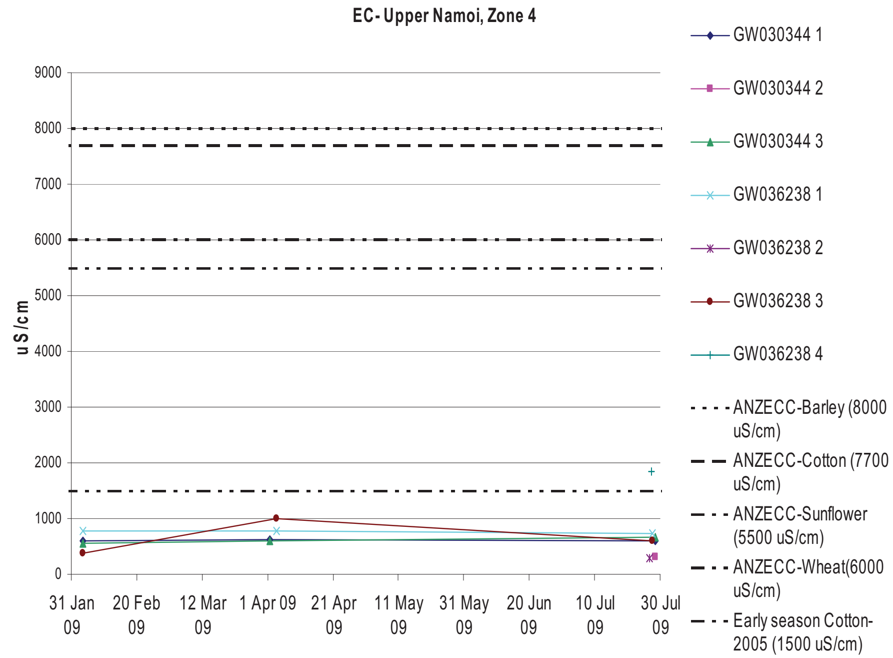
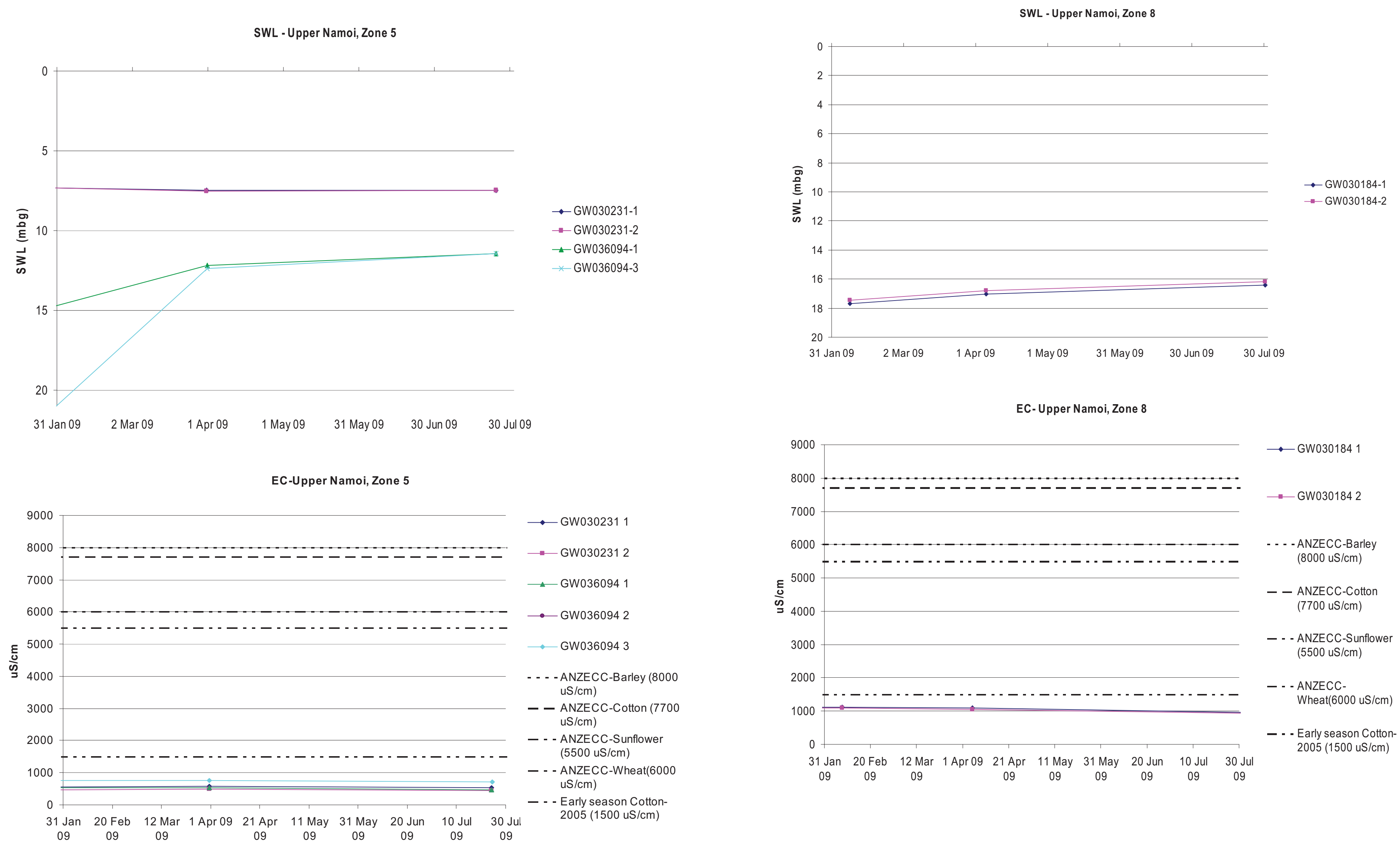


Figure
24

WRL

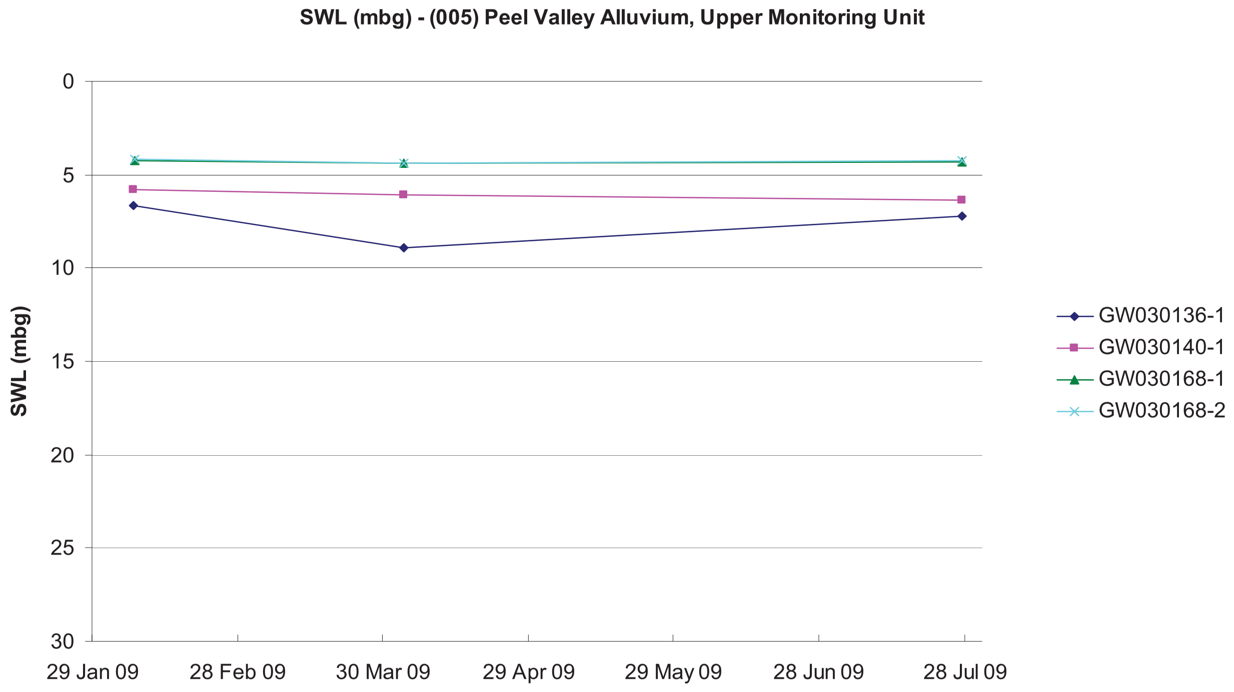
Report No. 2009/25

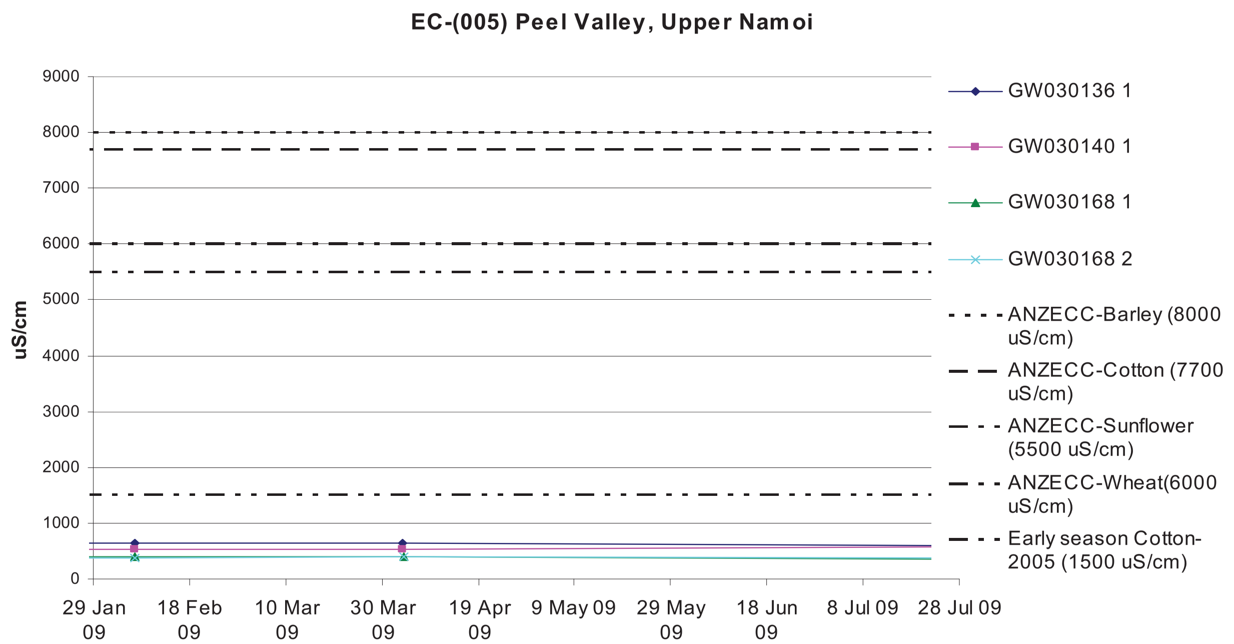


SWL & EC, WRL MONITORING 2009

UPPER NAMOI ALLUVIUM, ZONE 5 & ZONE 8

Figure 25





WRL Report No. 2009/25	SWL & EC, WRL MONITORING 2009 PEEL VALLEY ALLUVIUM, UPPER MONITORING UNIT	Figure 26

WRL
Report No. 2009/25

BENEFICIAL USE BASED ON SALINITY
UPPER MONITORING UNIT

Figure
27

Namoi_5_11.mxd

N
W E
S

0 15 30 60 Kilometres

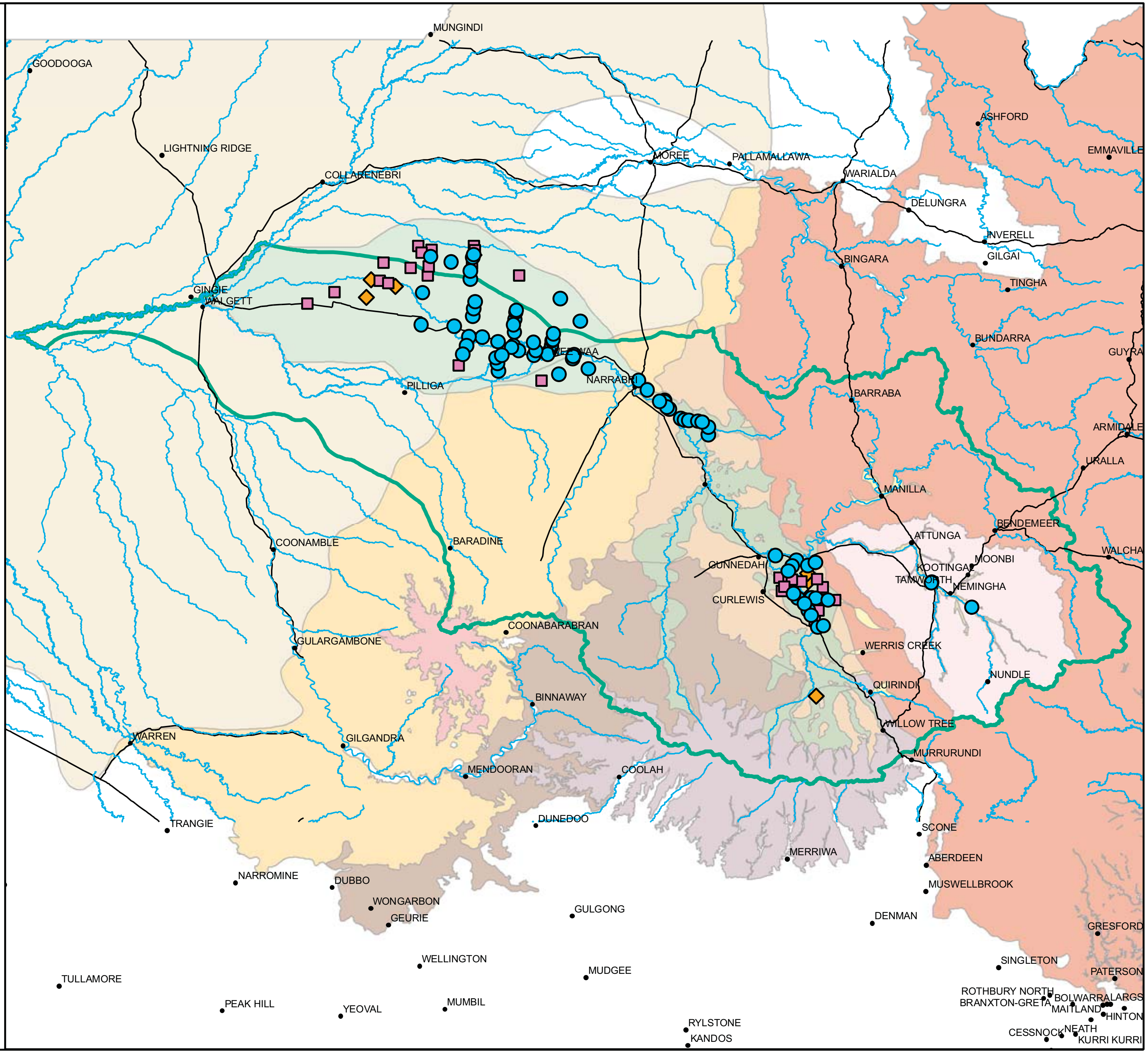
GDA94 (Lat/Long)

Legend

- Drinking
- Irrigation and Poultry
- Live Stock
- Towns
- Major Rivers
- Major Roads
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

BENEFICIAL USE BASED ON SALINITY

LOWER MONITORING UNIT

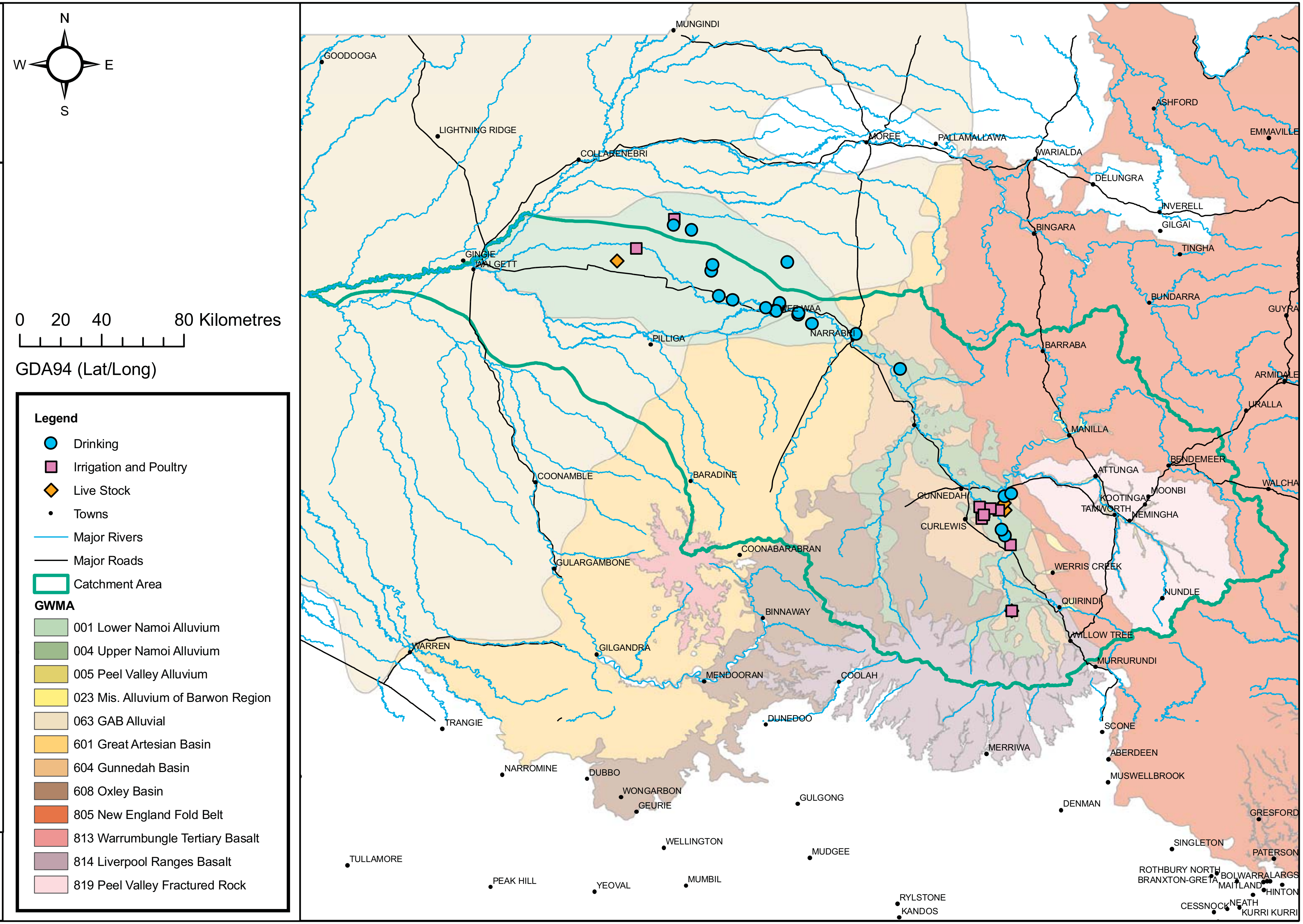


Figure 28

Namoi_5_12.mxd

BENEFICIAL USE BASED ON SALINITY
DEEPER MONITORING UNIT

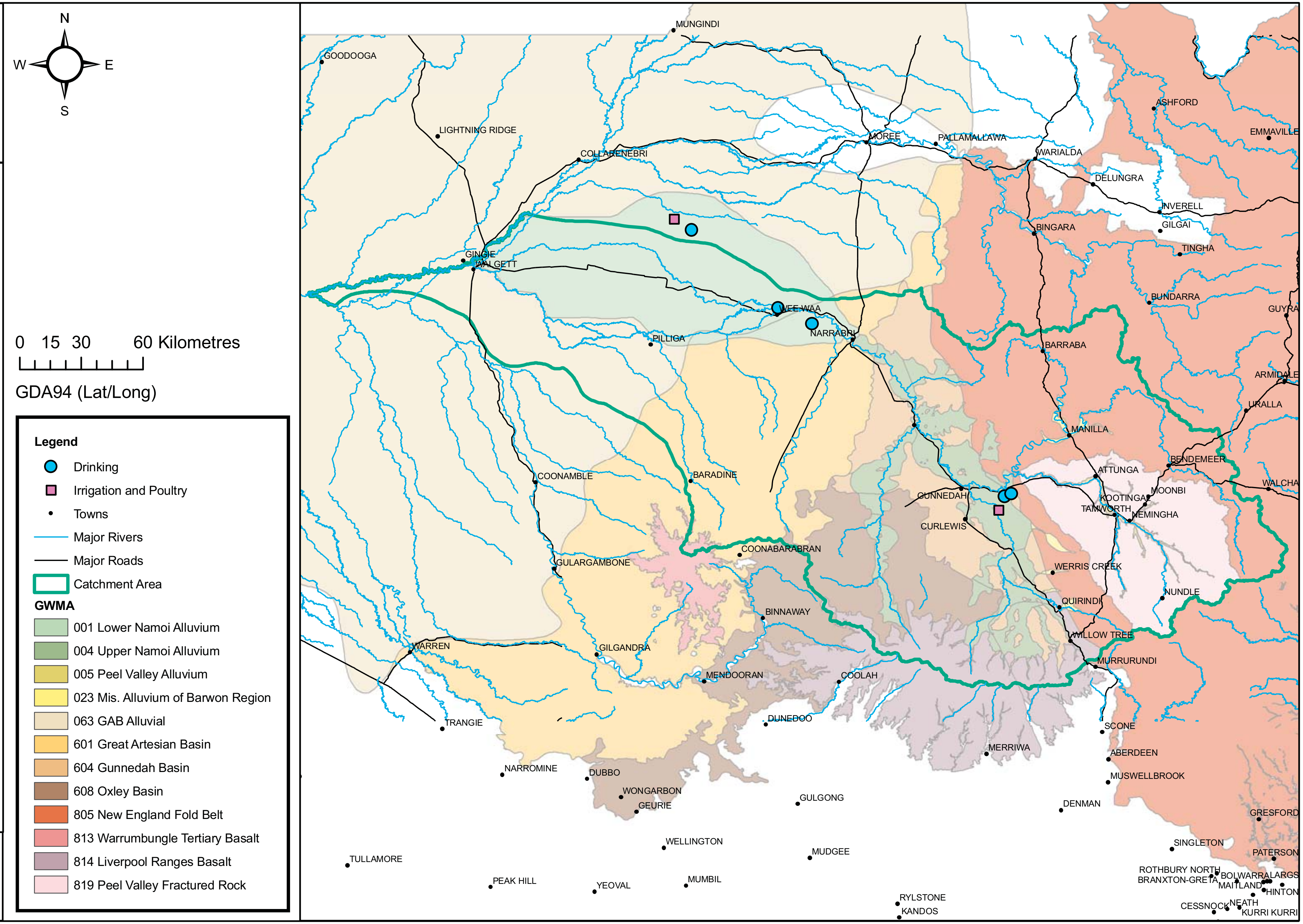
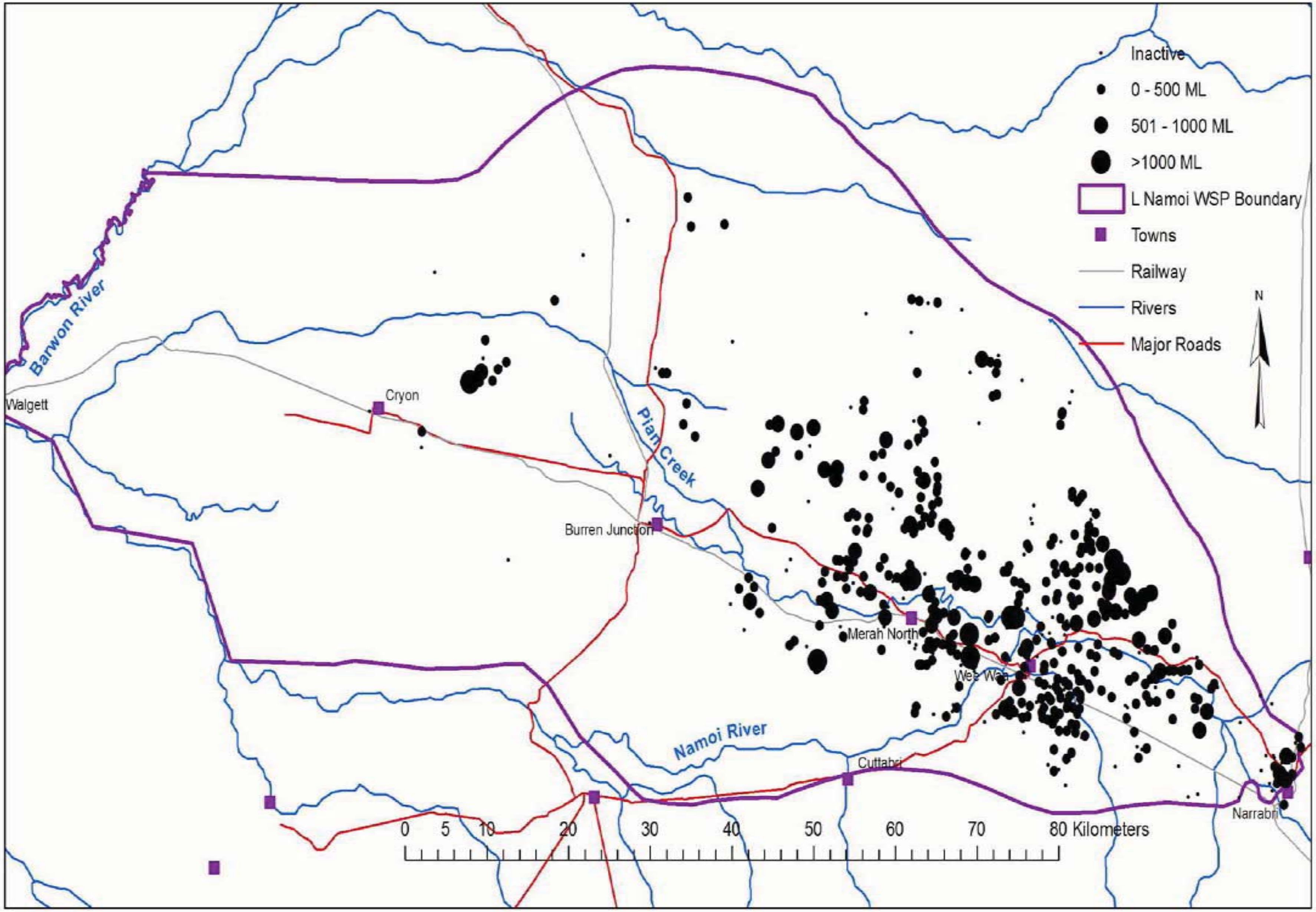


Figure
29

Namoi_5_13.mxd

AVERAGE GROUNDWATER USAGE 2002-2007
IN THE LOWER NAMOI

Figure 30



Source: Smithson (2009)

WRL
Report No. 2009/25

NAMOI SOIL SALINITY

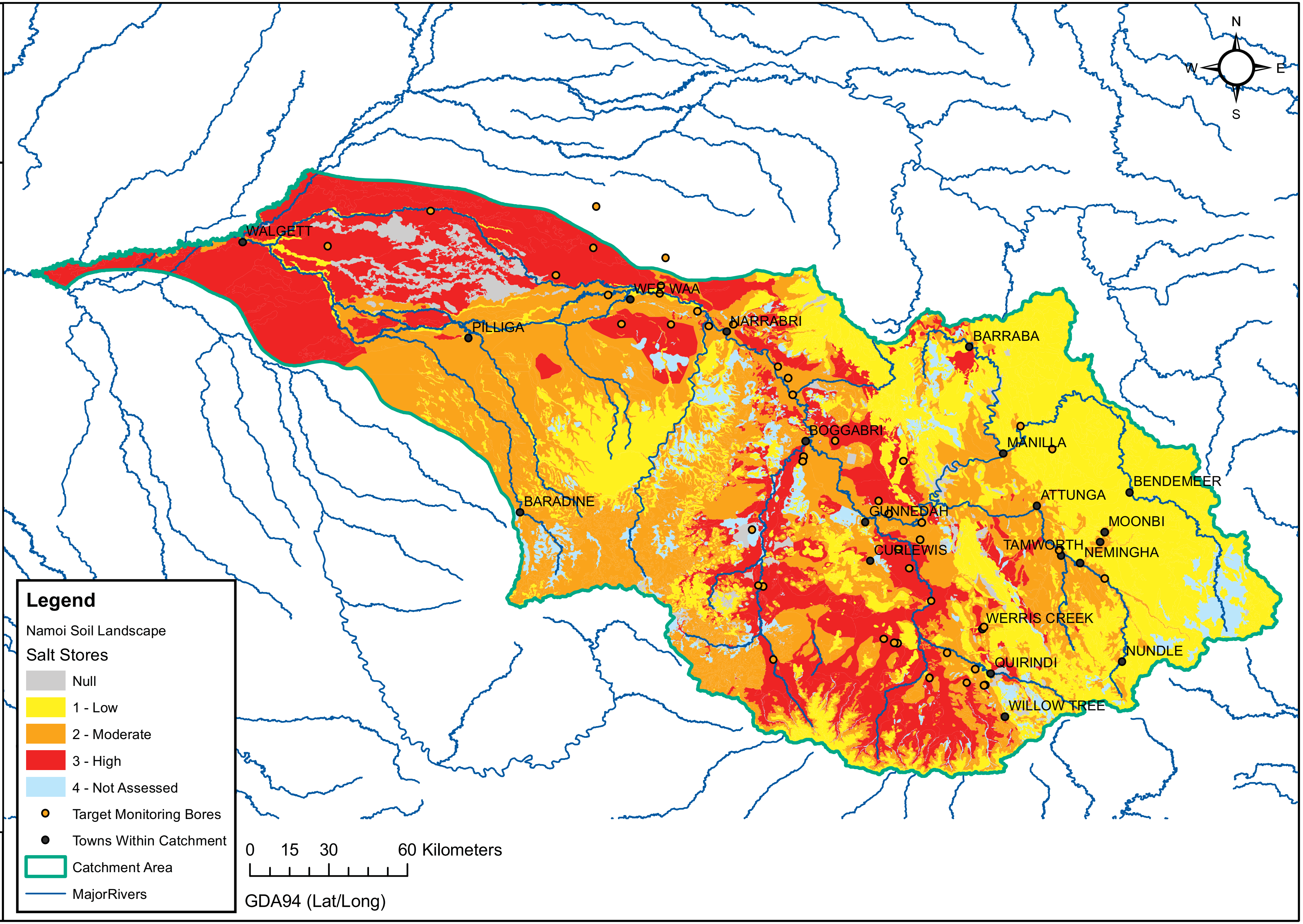
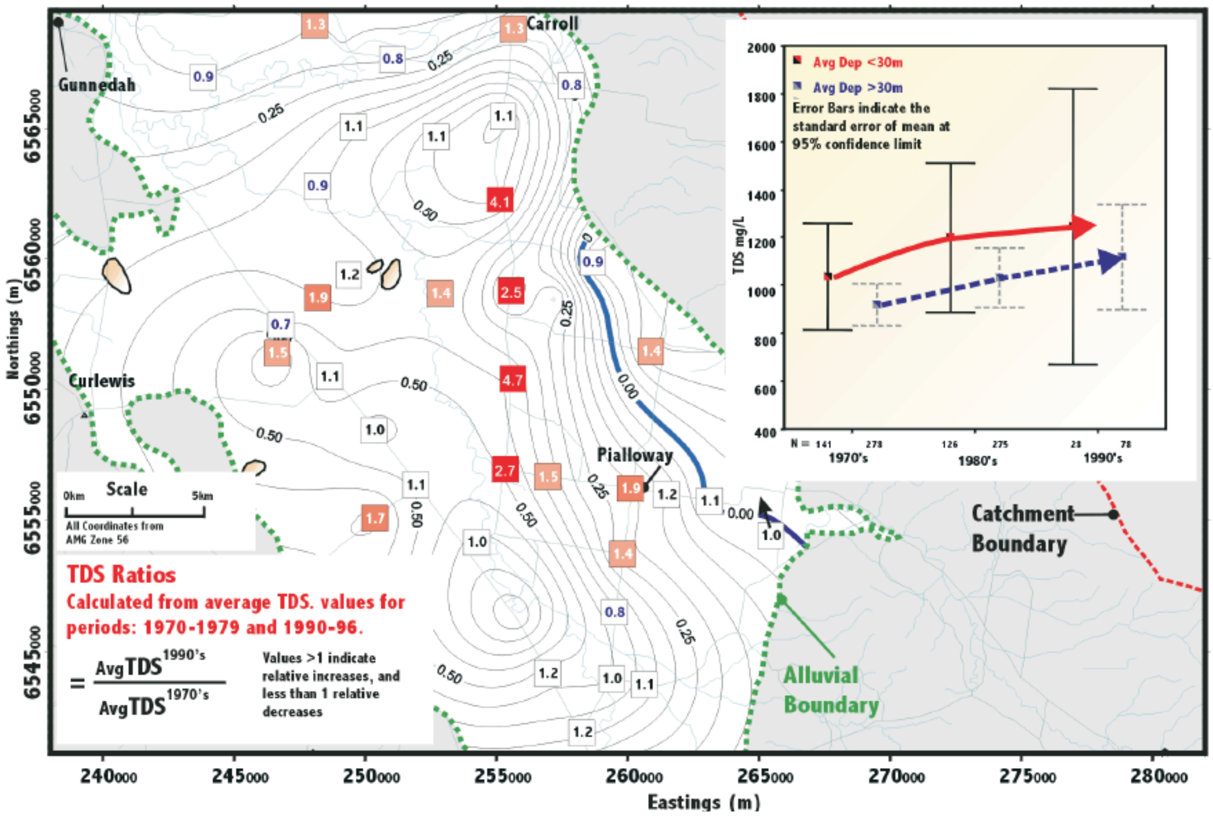


Figure
31

Namoi_1_5.mxd



Source: Lavitt (1999)

WRL Report No. 2009/25	VARIATION IN GROUNDWATER SALINITY (TDS) FROM 1970'S TO 1990'S IN ZONE 3	Figure 32

WRL
Report No. 2009/25

SALINITY CHANGE UPPER MONITORING UNIT
AVERAGES OF 1980-1999 COMPARED WITH 2000-2009

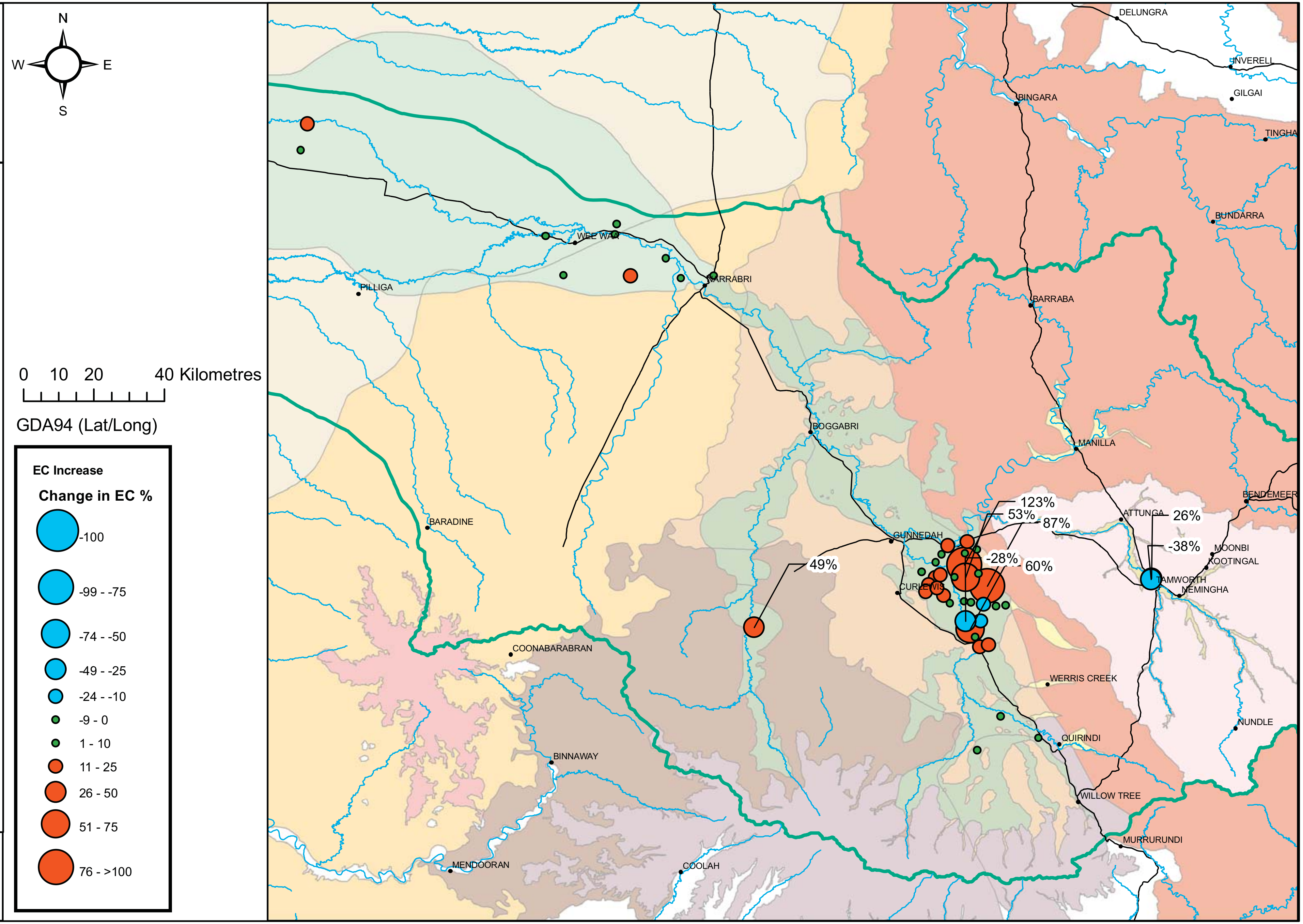


Figure
33

Namoi_5_10Upper.mxd

WRL

Report No. 2009/25

SALINITY CHANGE UPPER MONITORING UNIT (UPPER NAMOI)
AVERAGES OF 1980-1999 COMPARED WITH 2000-2009

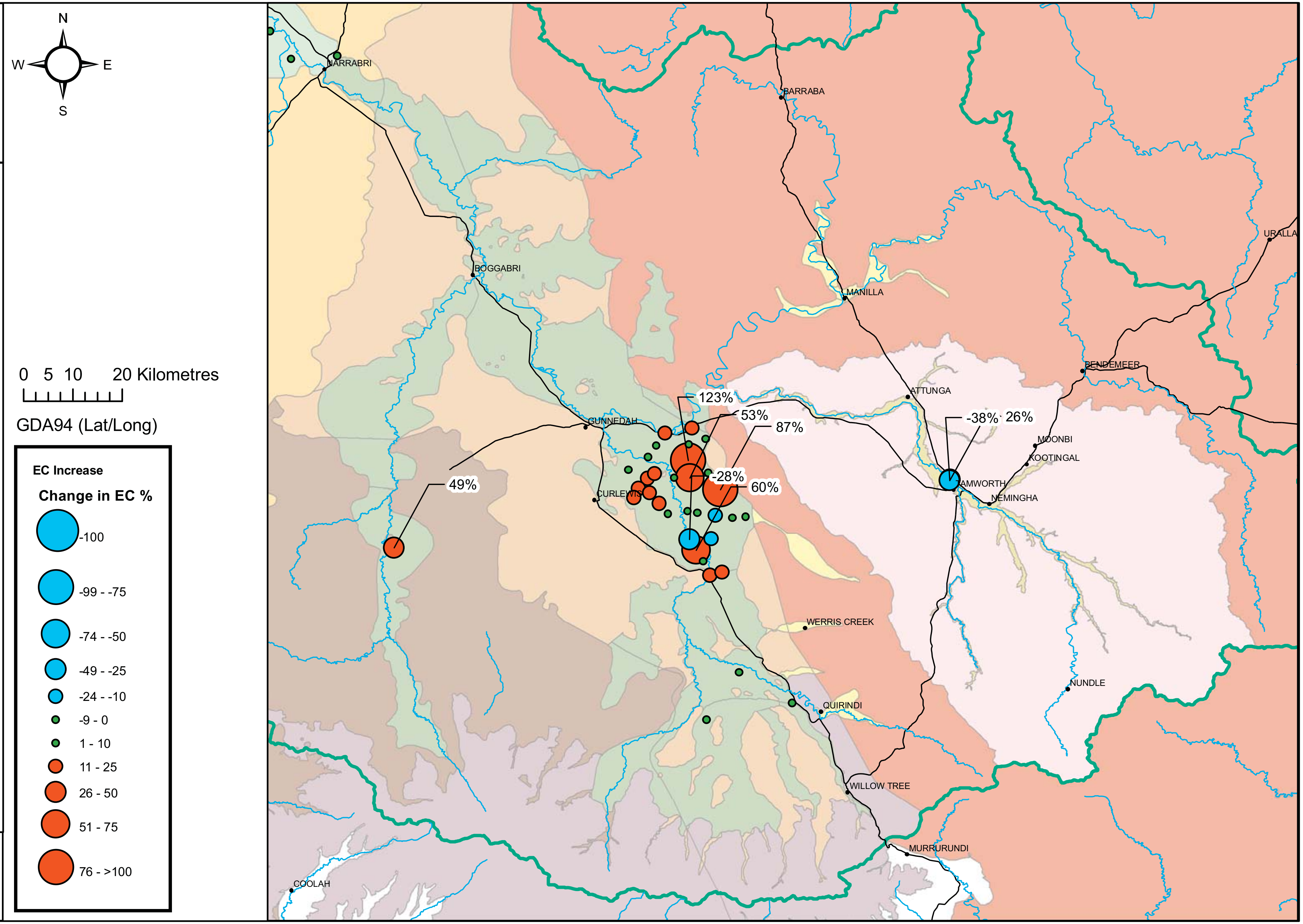
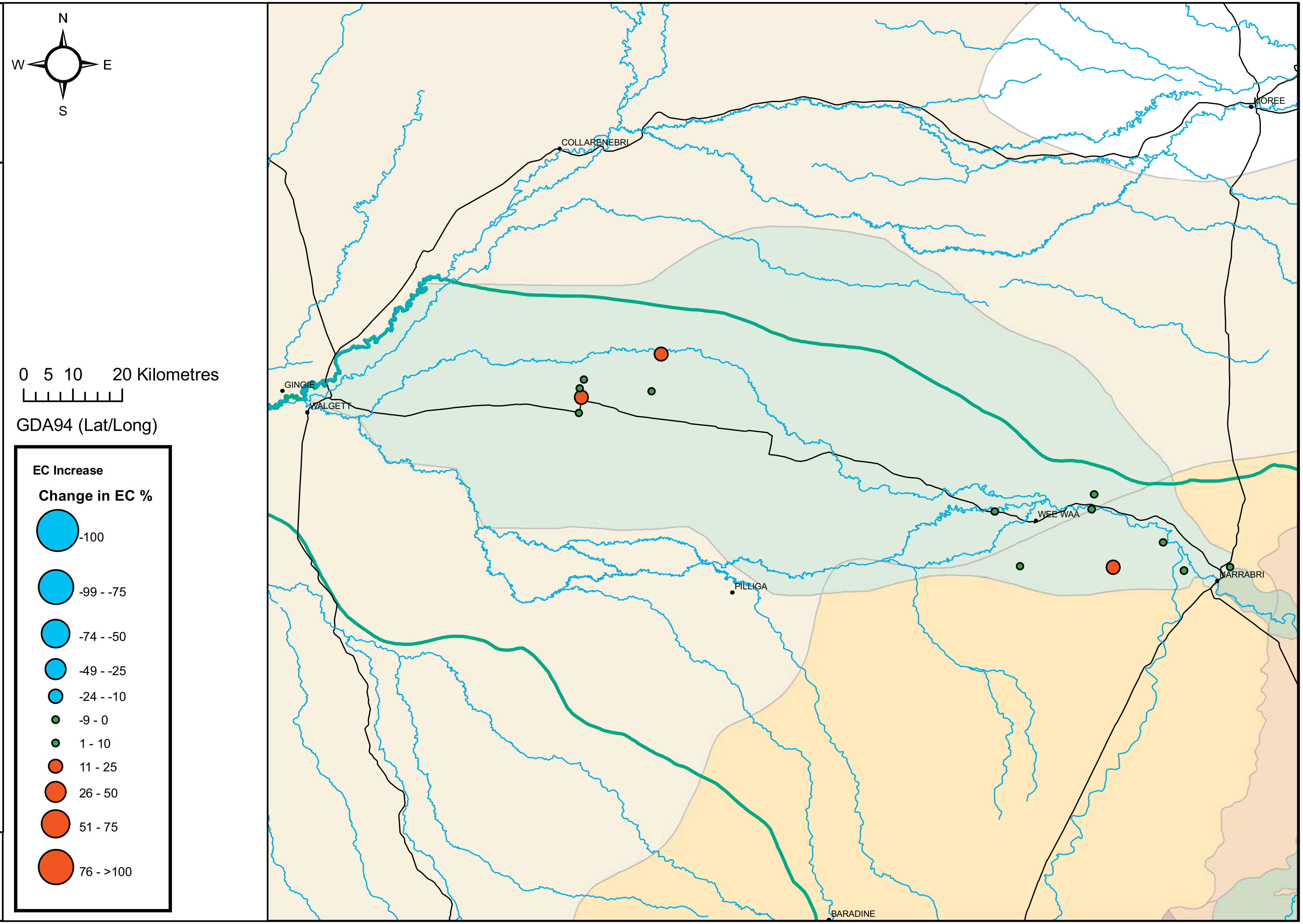


Figure 34

Namoi_5_10Upper.mxd



WRL
Report No. 2009/25

SALINITY CHANGE UPPER MONITORING UNIT (LOWER NAMOI)
AVERAGES OF 1980-1999 COMPARED WITH 2000-2009

Figure 35

Namoi_5_10Upper.mxd

WRL

Report No. 2009/25

SALINITY CHANGE LOWER MONITORING UNIT
AVERAGES OF 1980-1999 COMPARED WITH 2000-2009

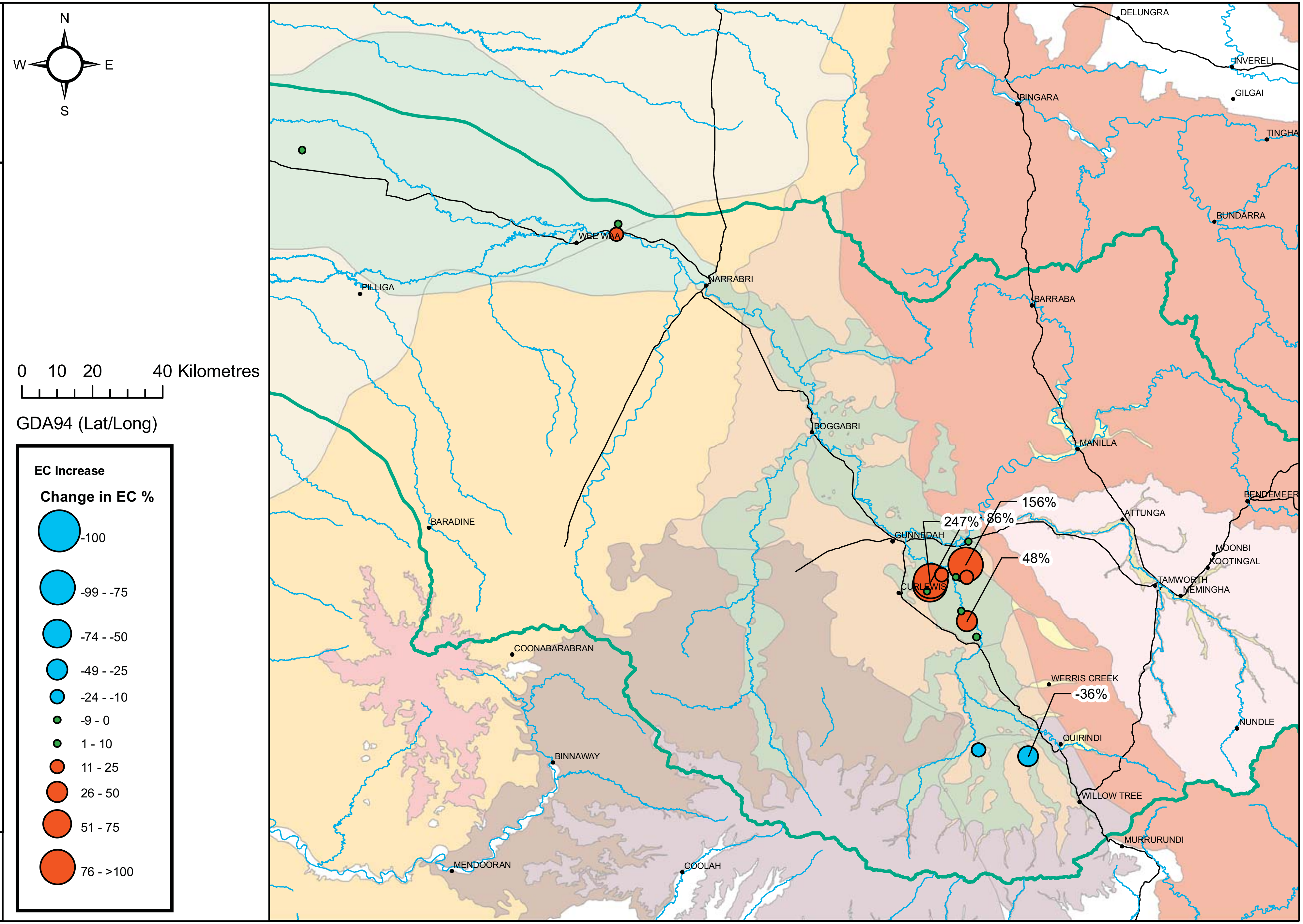


Figure
36

Namoi_5_10_Lower.mxd

WRL
Report No. 2009/25

REPRESENTATIVE BORES IN THE NAMOI CATCHMENT FOR HYDROGRAPH ANALYSIS

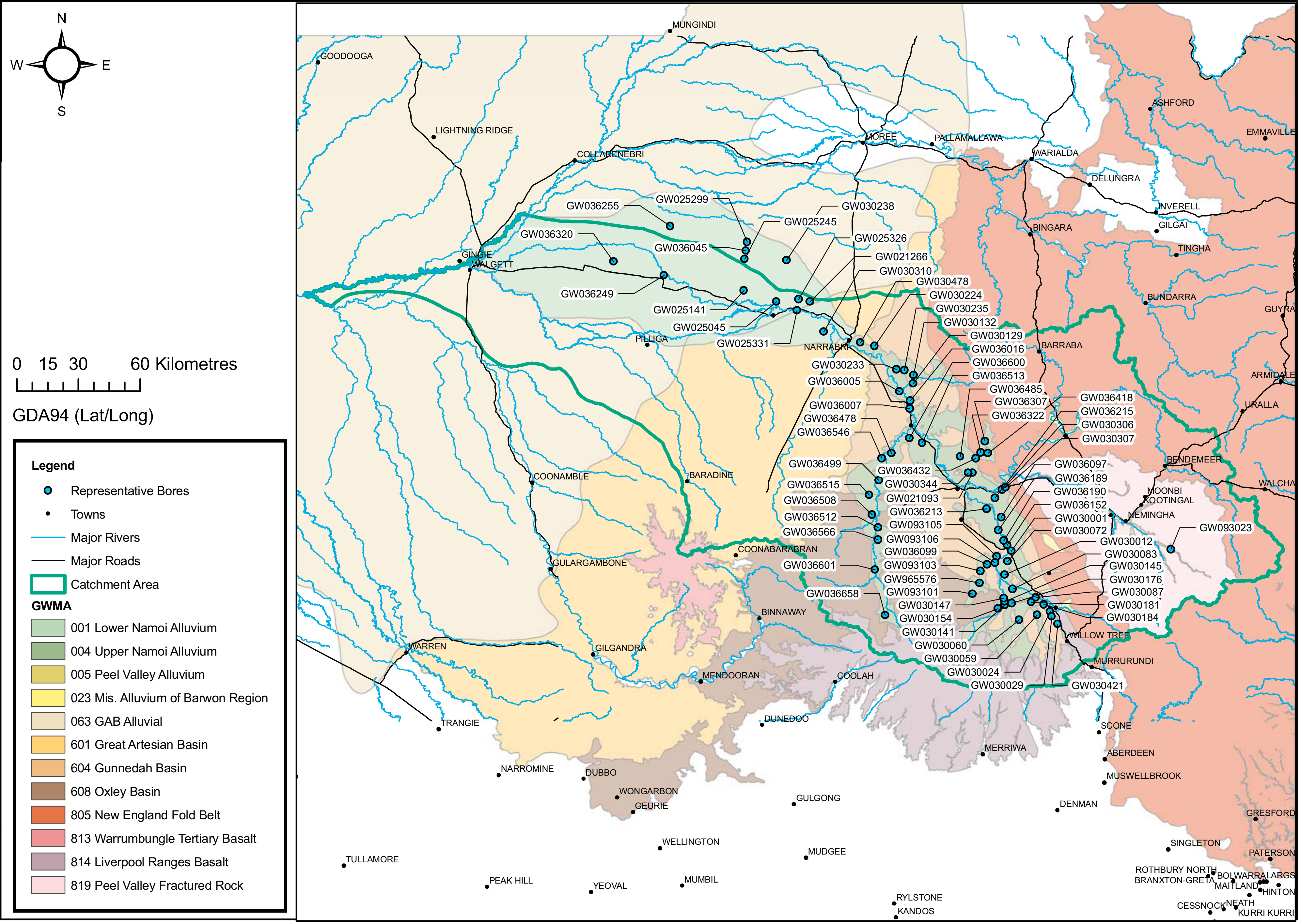
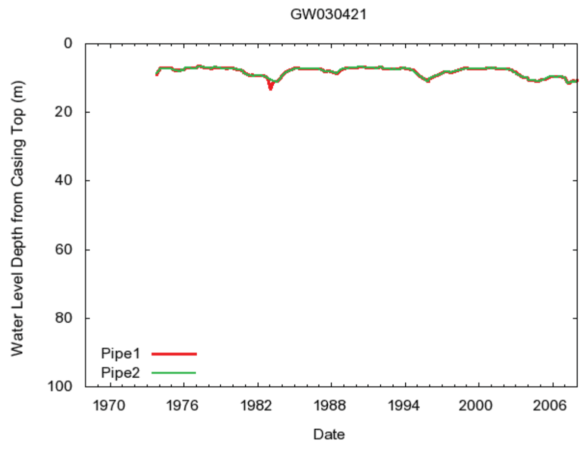
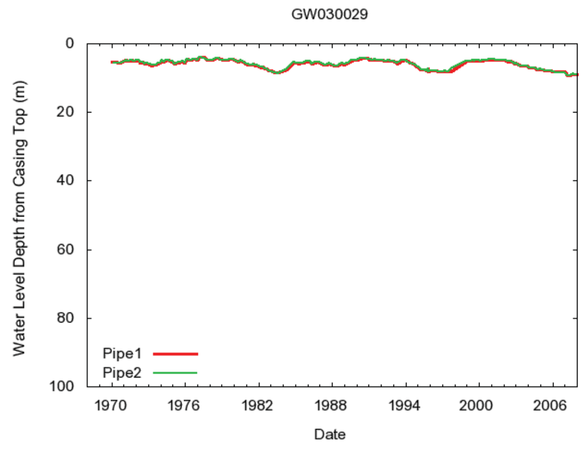
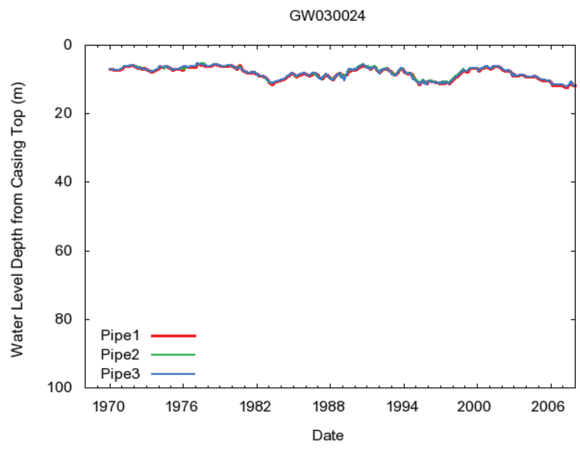


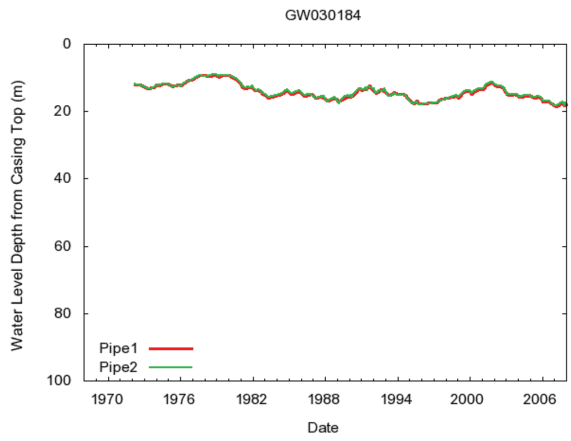
Figure
37

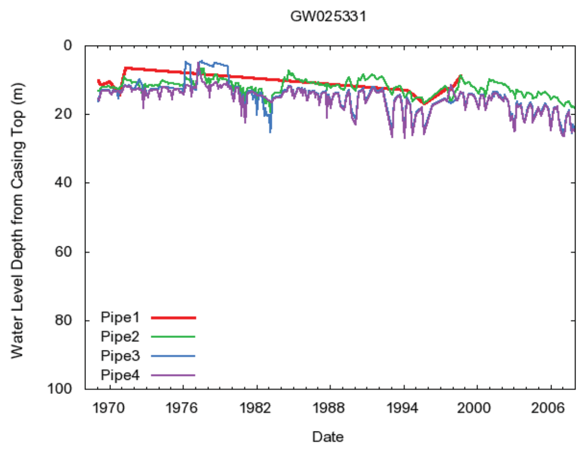
Namoi_2_8.mxd







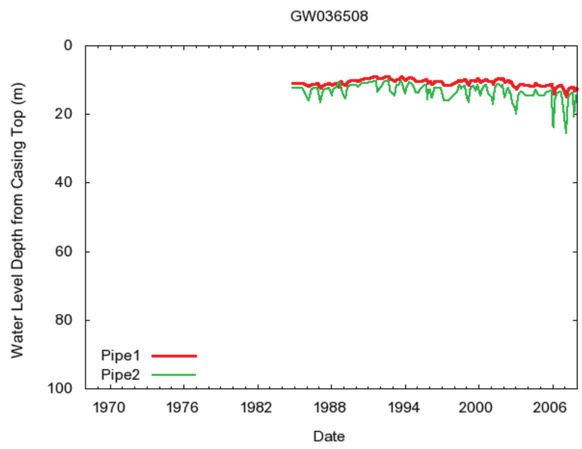


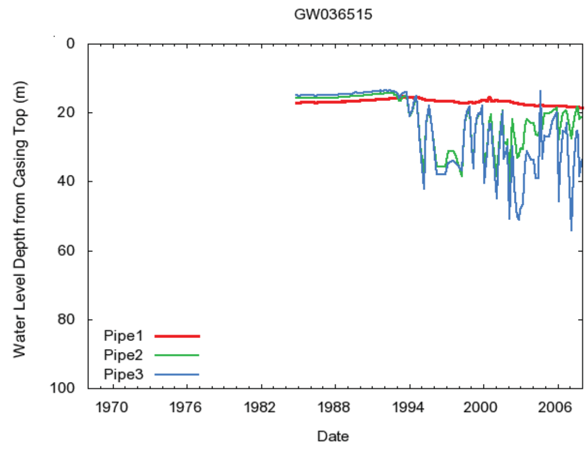


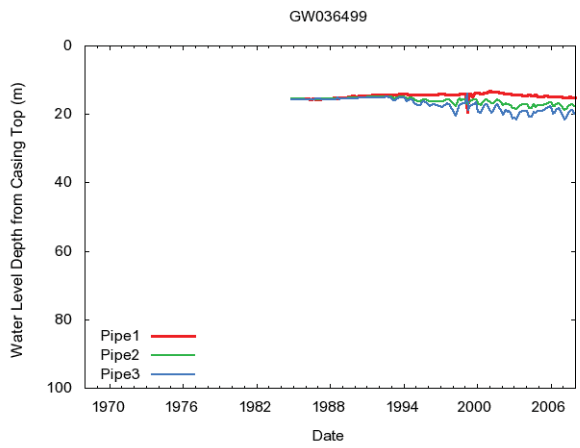
WRL
Report No. 2009/25

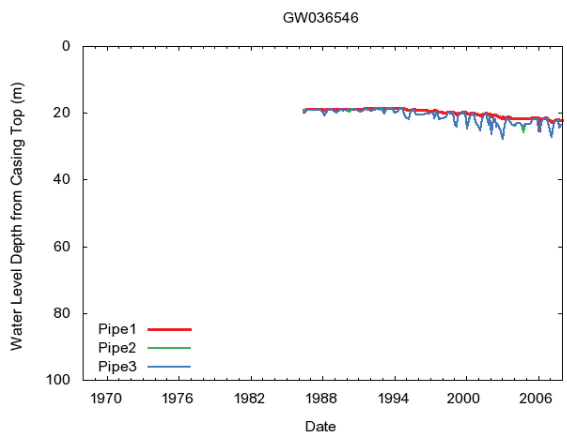
HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI
ZONE 1

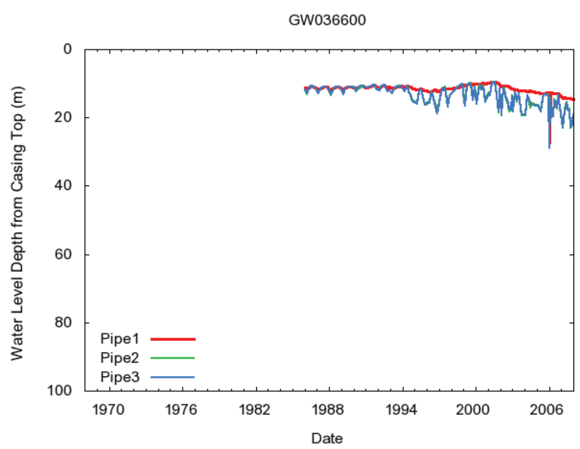
Figure
38

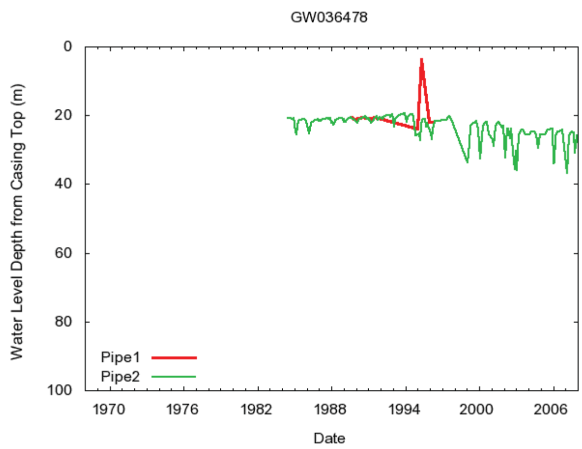




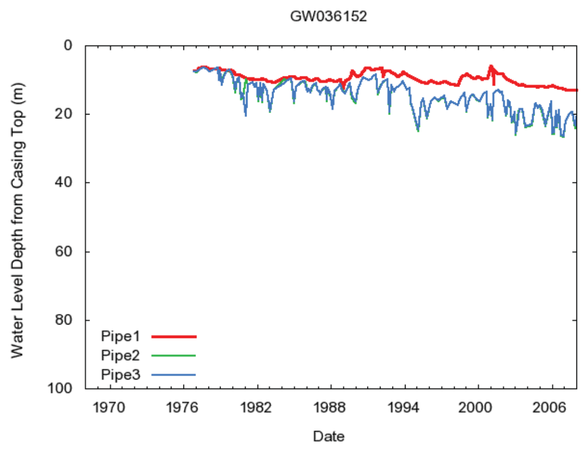


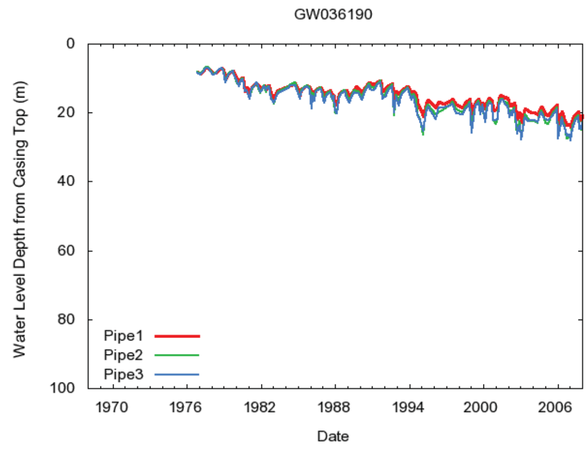


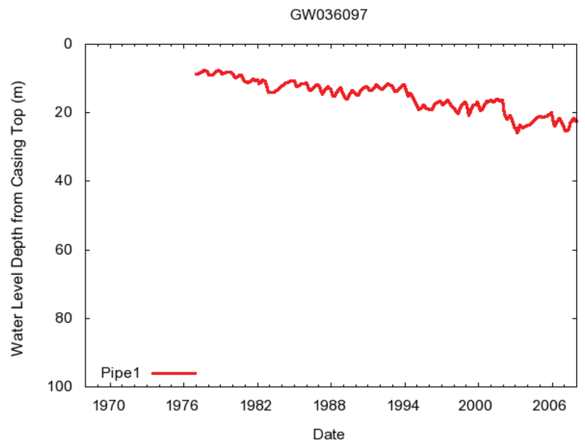


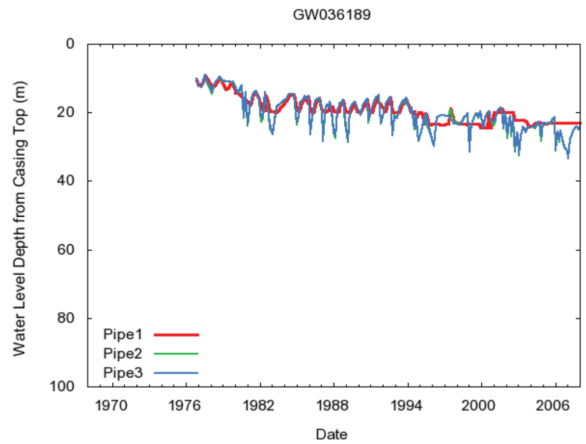


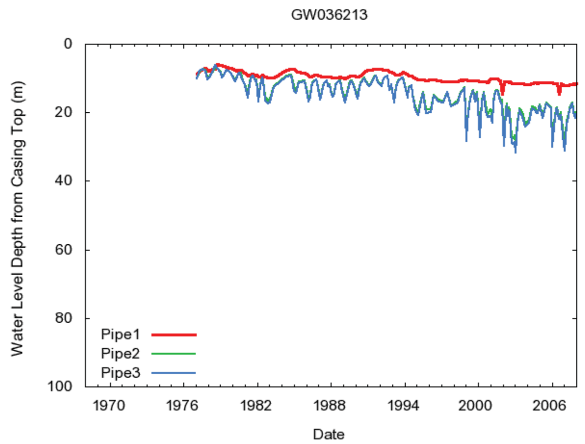
WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 2	Figure 39

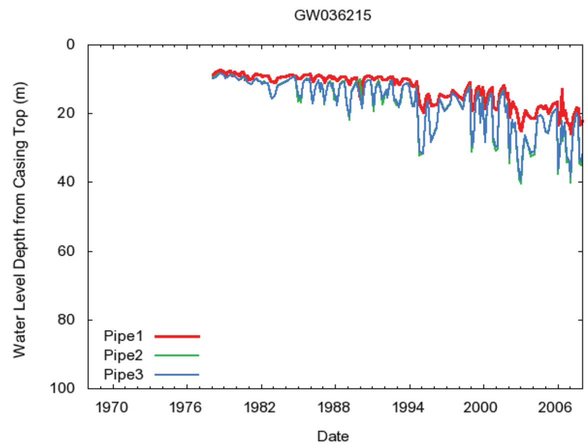


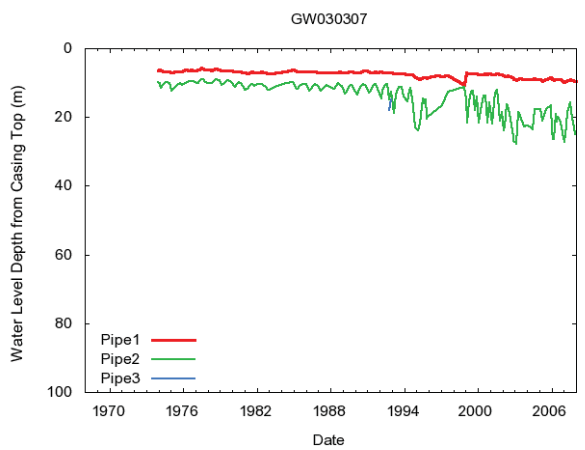




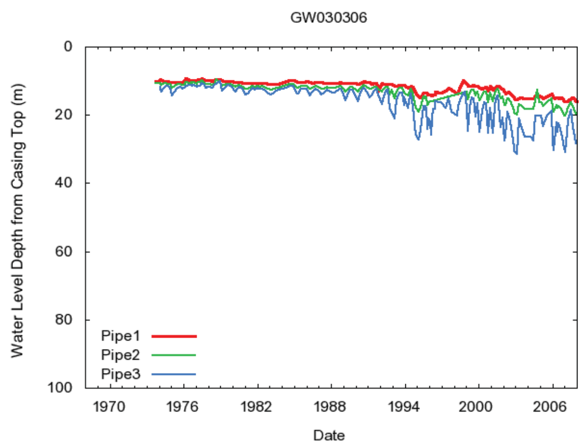


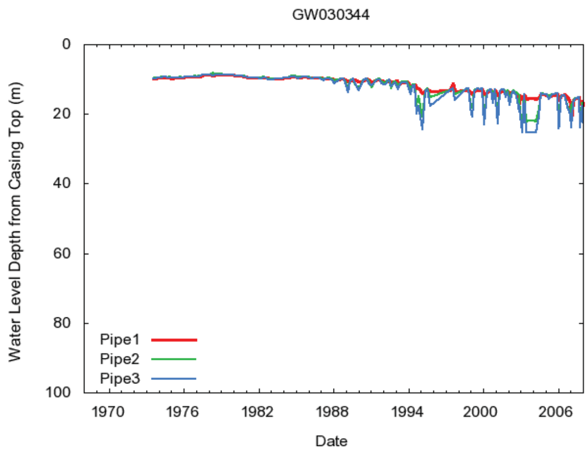


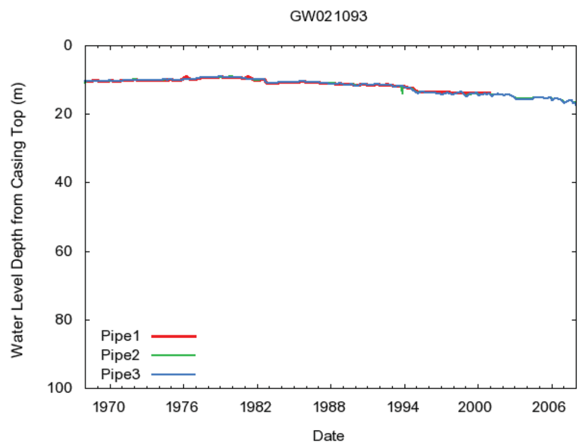


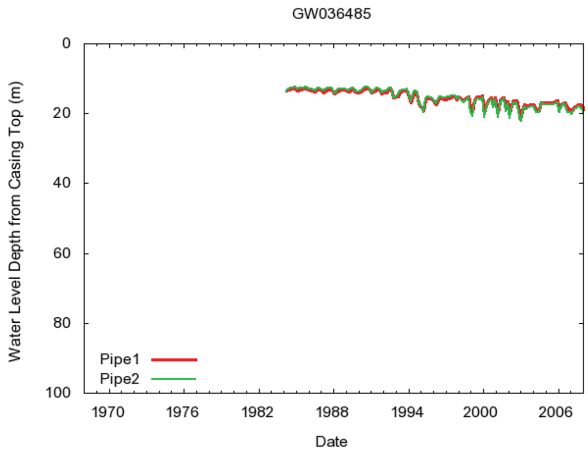


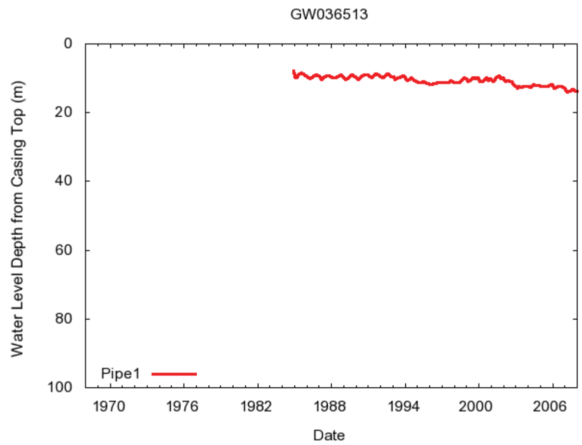
WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 3	Figure 40

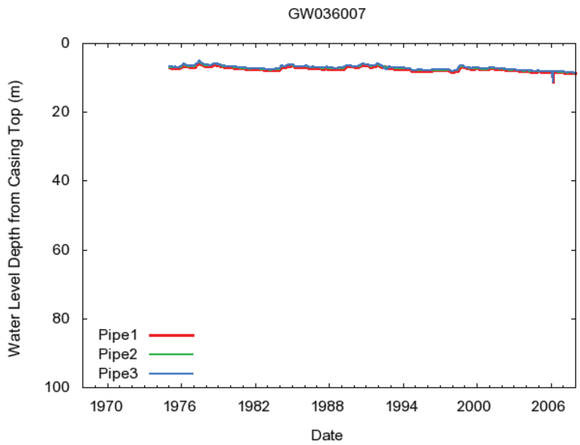




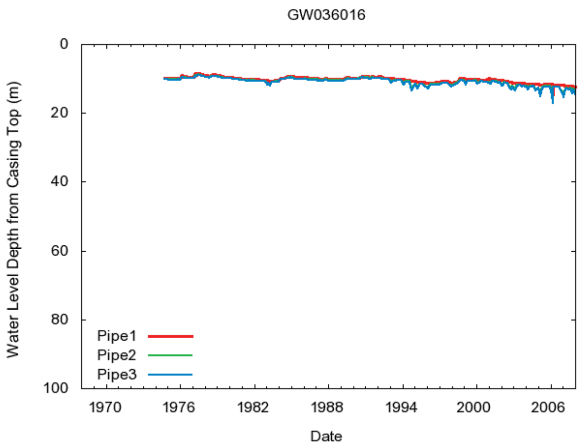


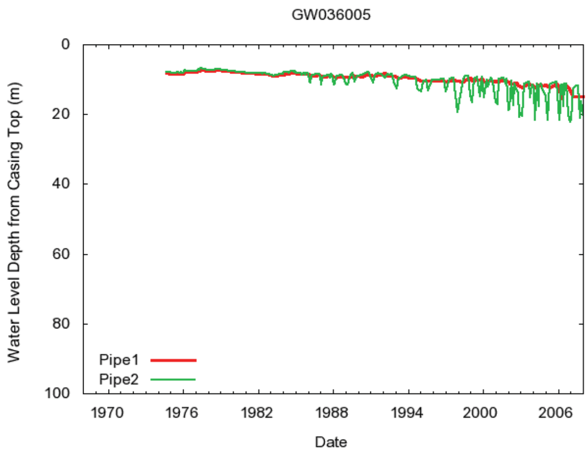


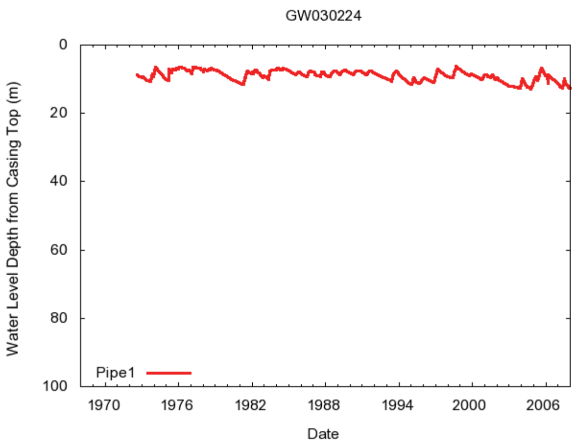


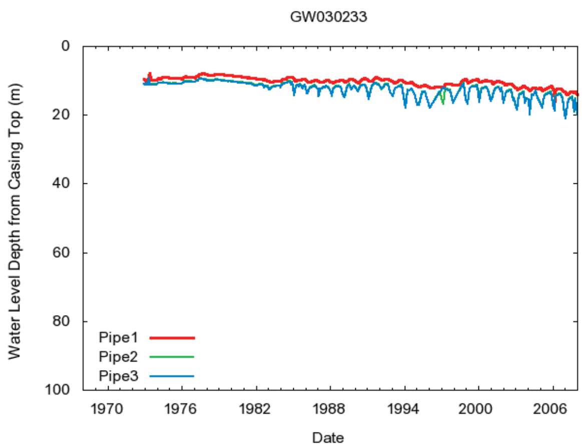


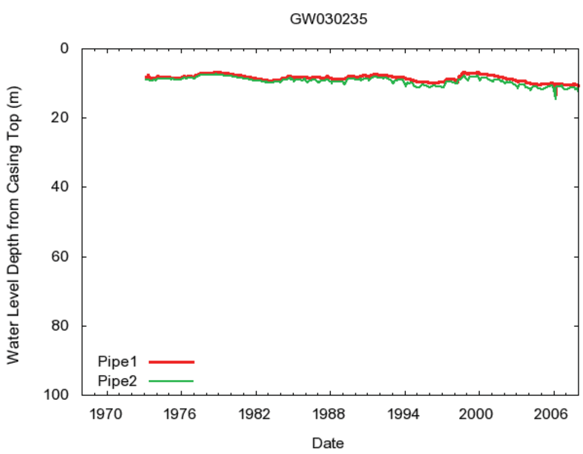
WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 4	Figure 41

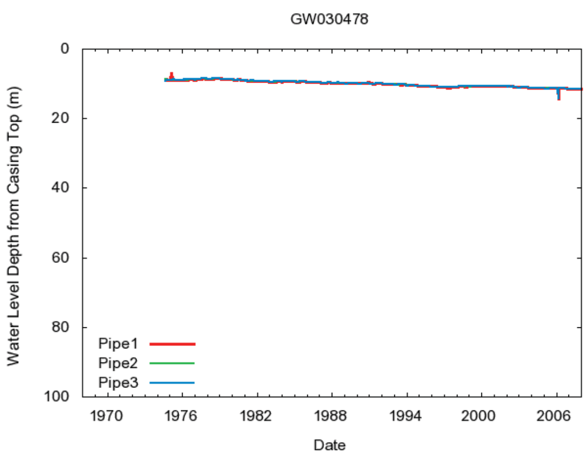




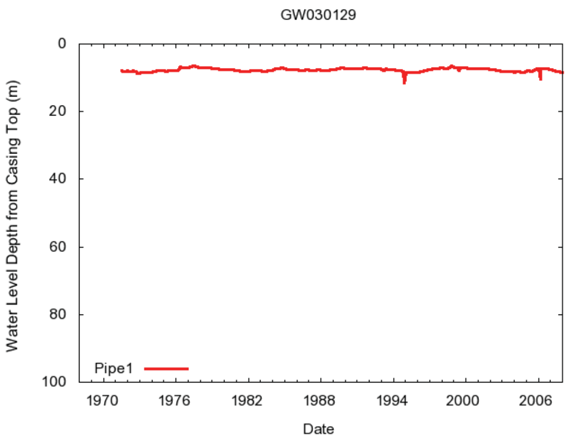


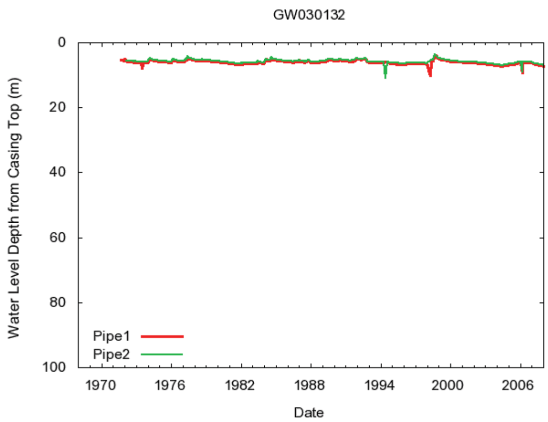


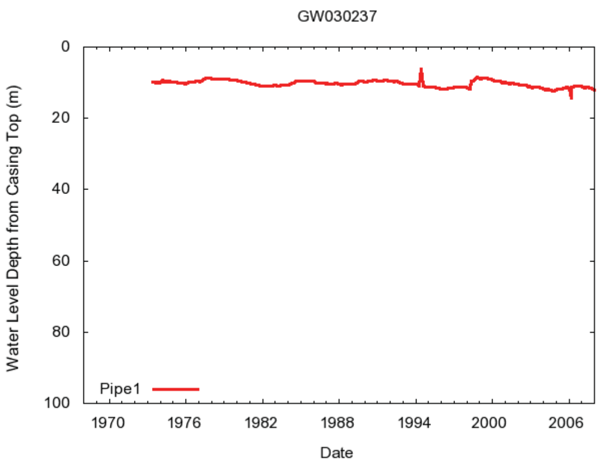




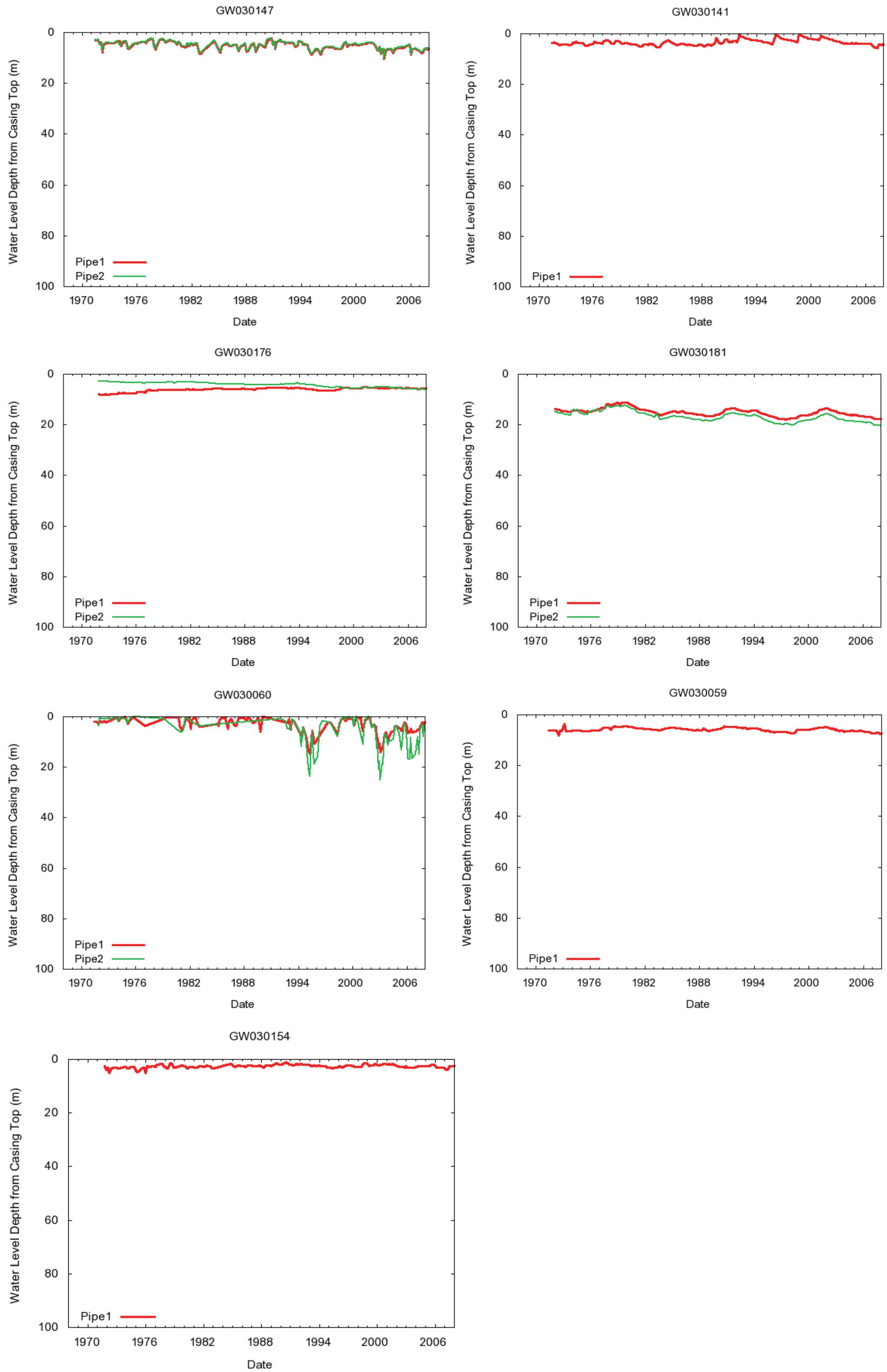
WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 5 & 11	Figure 42



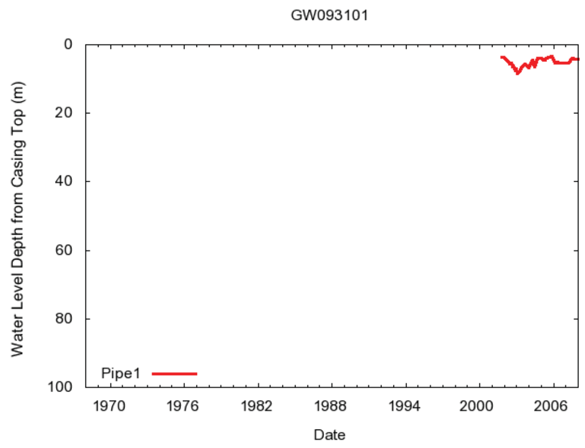


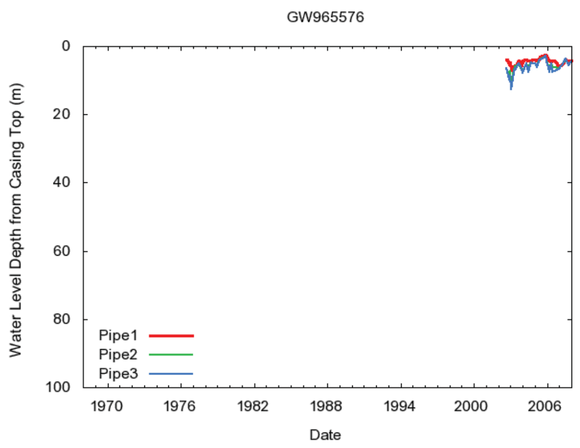


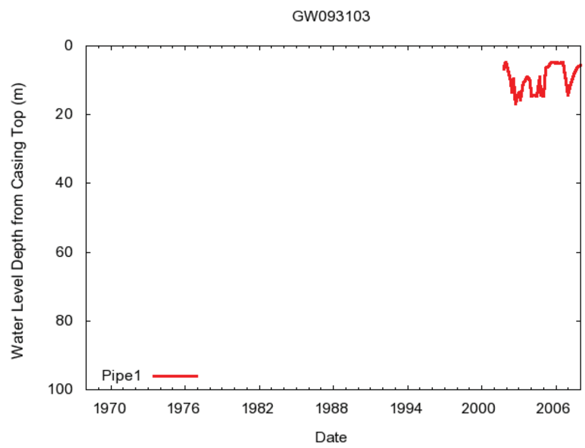
WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 5 & 11 (CONTINUED)	Figure 43

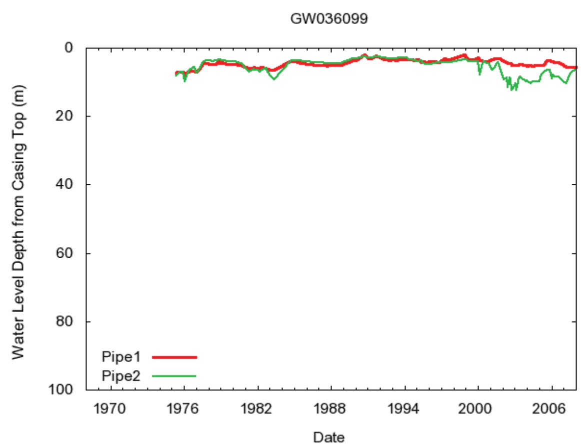


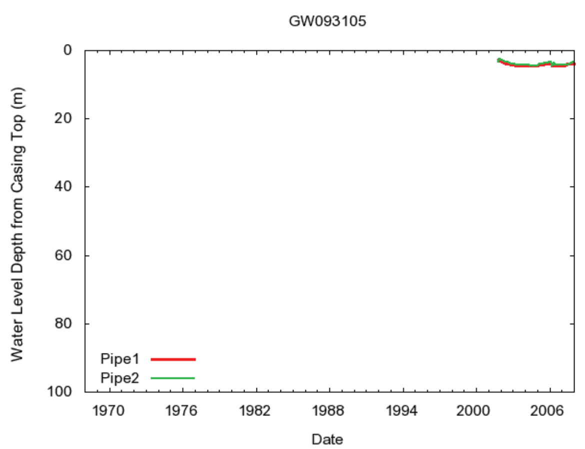
WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 6 & 10	Figure 44

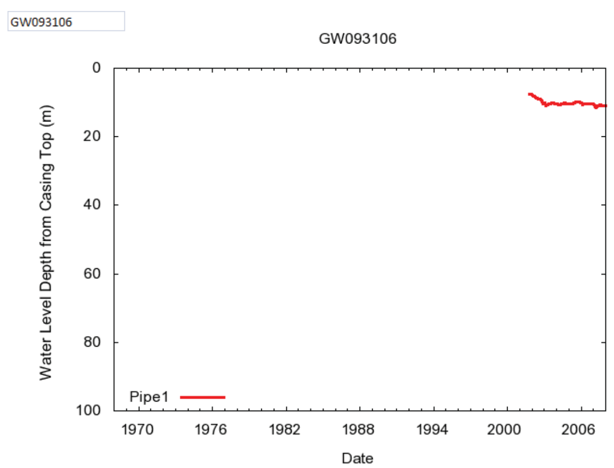




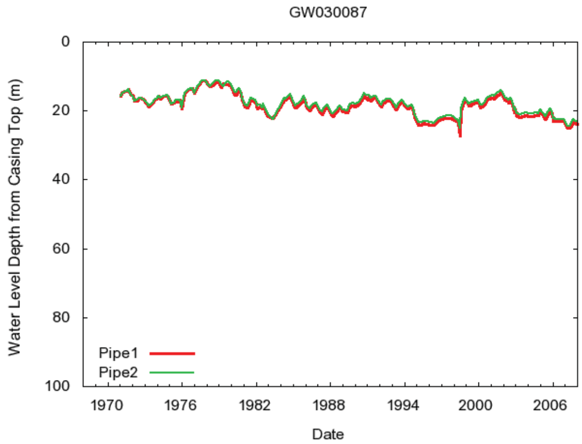


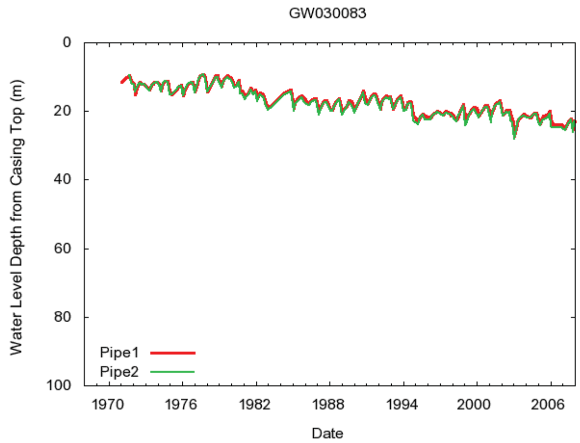


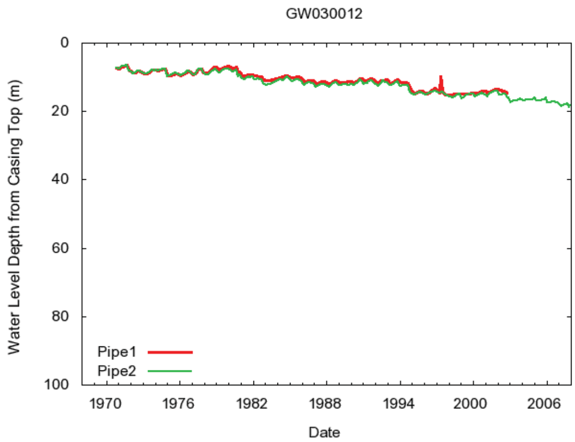


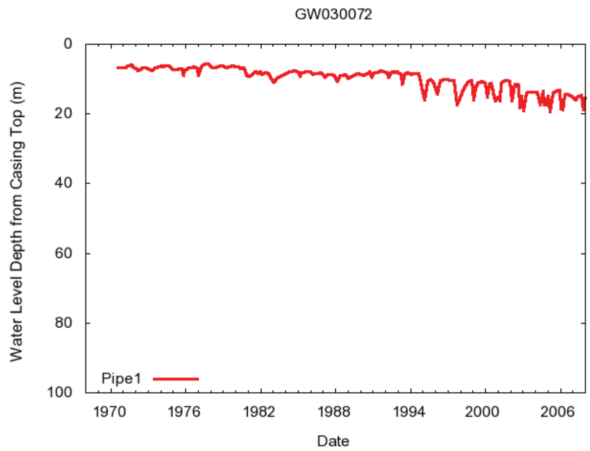


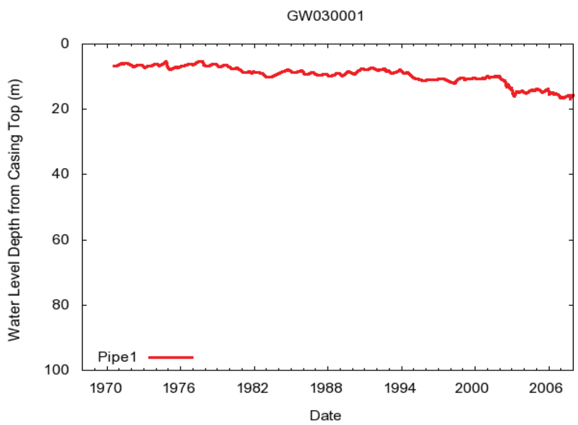
WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 7	Figure 45



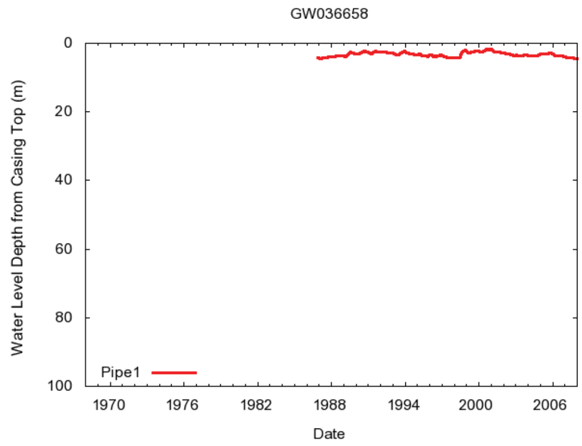


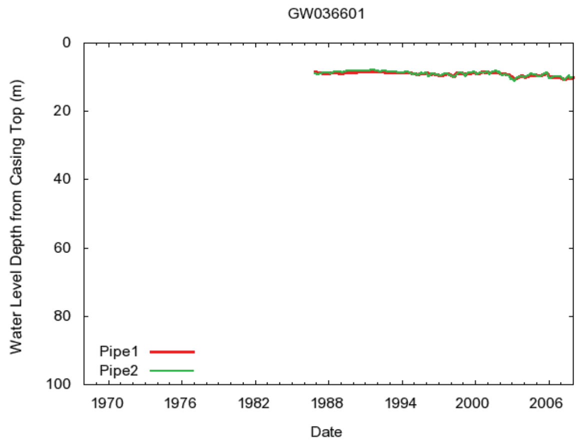


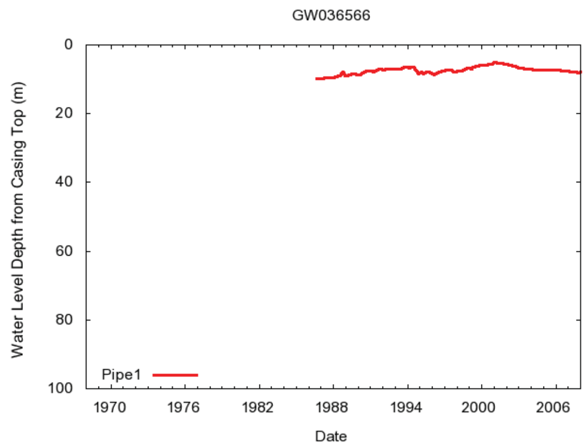


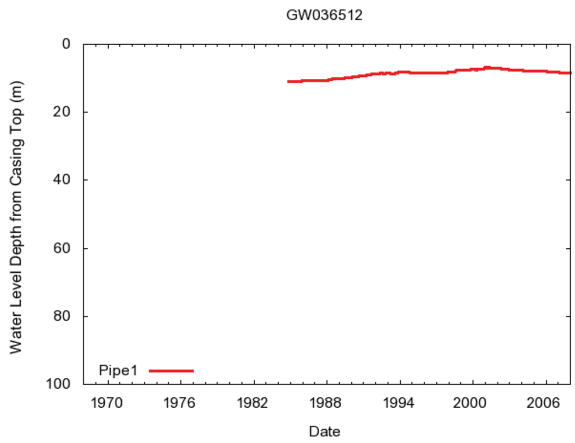


WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 8	Figure 46

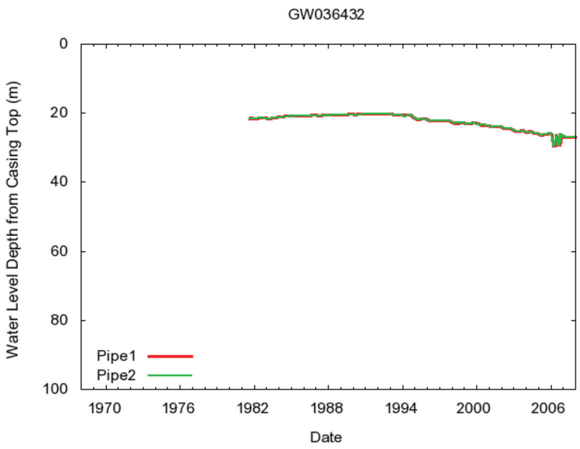


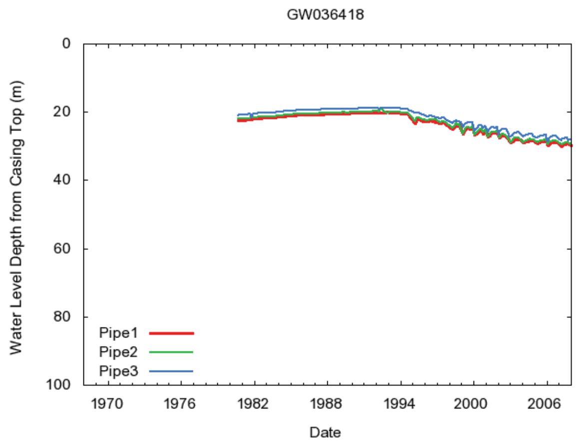


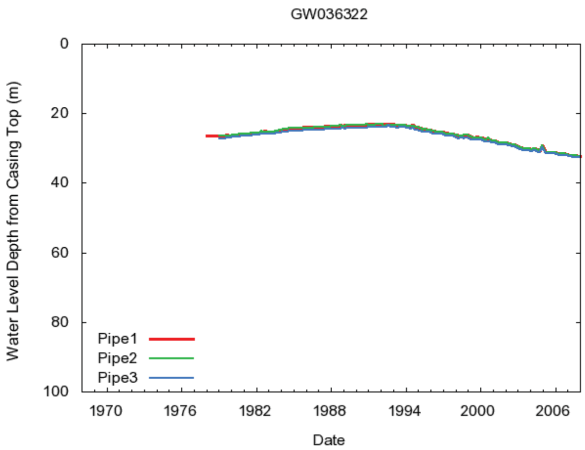


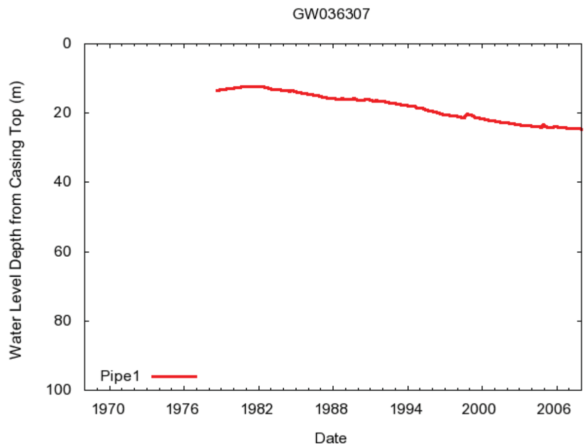


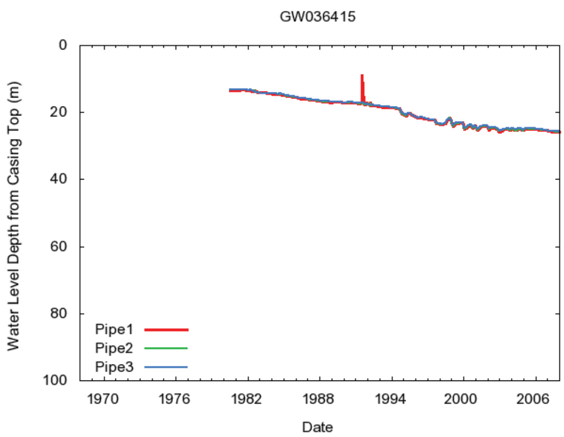
WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 9	Figure 47



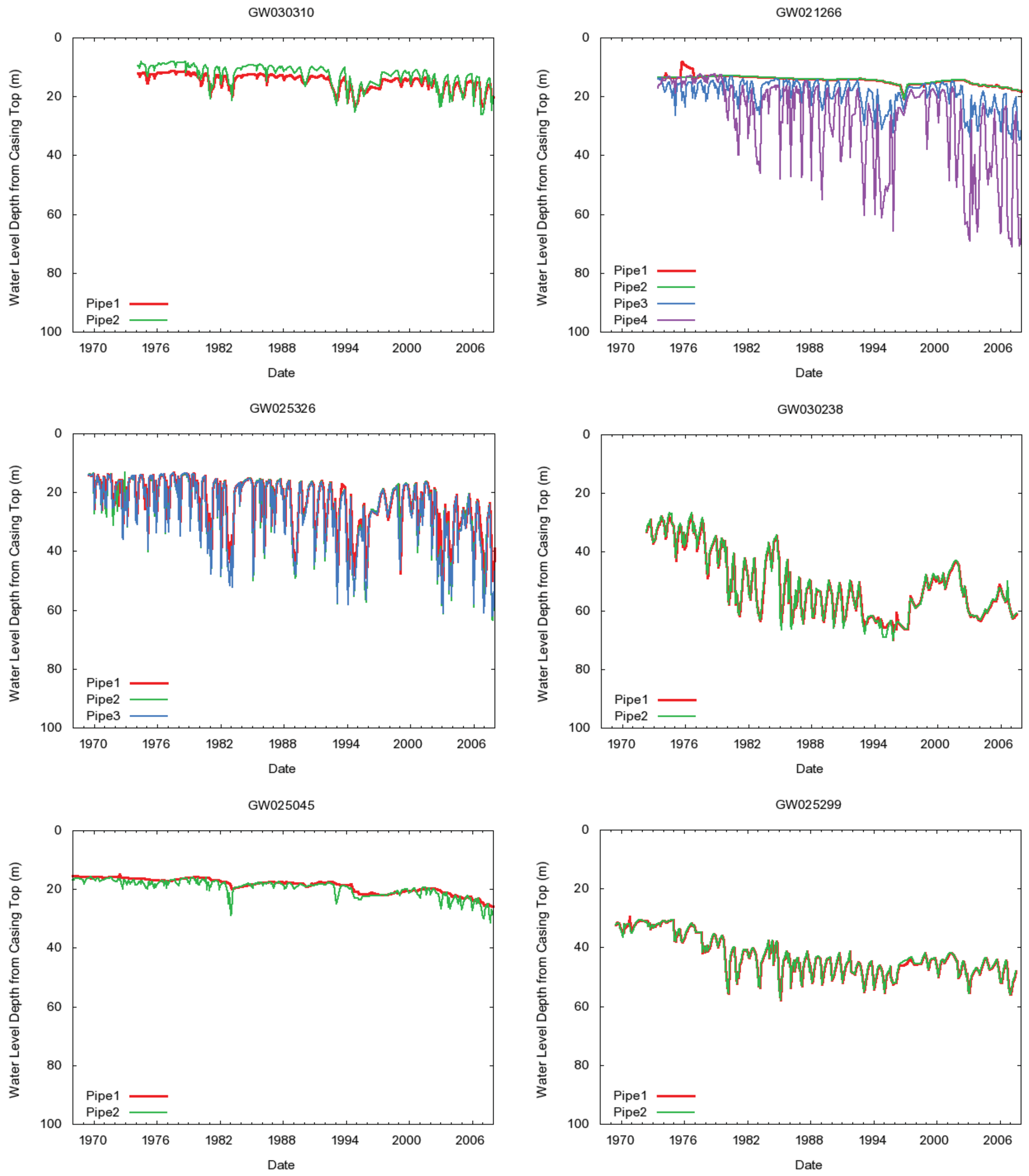




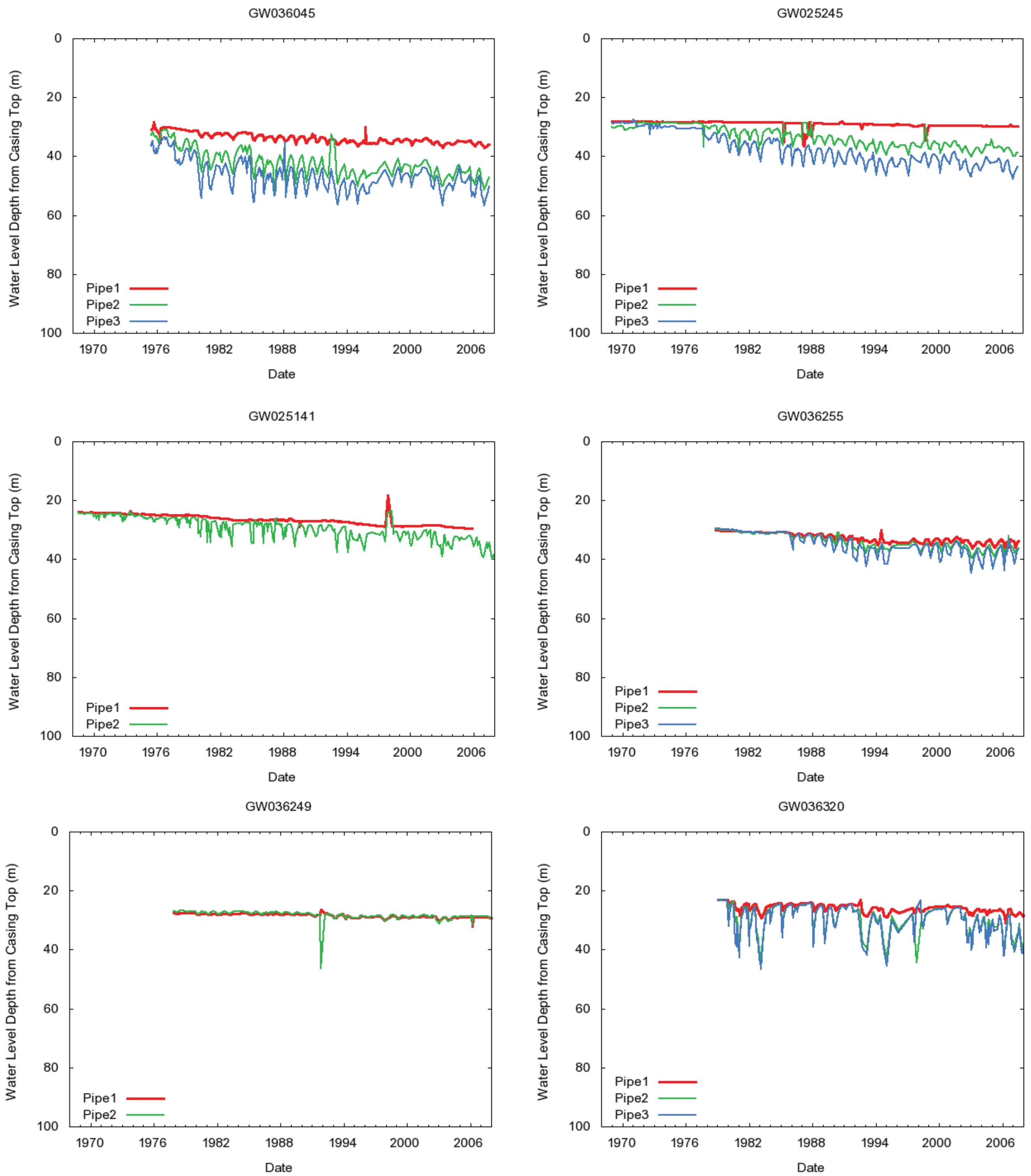




WRL Report No. 2009/25	HYDROGRAPHS 1970's TO MID 2008, UPPER NAMOI ZONE 12	Figure 48



WRL Report No.2009/25	HYDROGRAPHS 1970'S TO MID 2008, LOWER NAMOI	Figure 49



HYDROGRAPHS 1970'S TO MID 2008, LOWER NAMOI
(CONTINUED)

WRL

Report No. 2009/25

GROUNDWATER LEVEL CHANGE 1978-2006 (RECOVERED) UPPER MONITORING UNIT, UPPER NAMOI

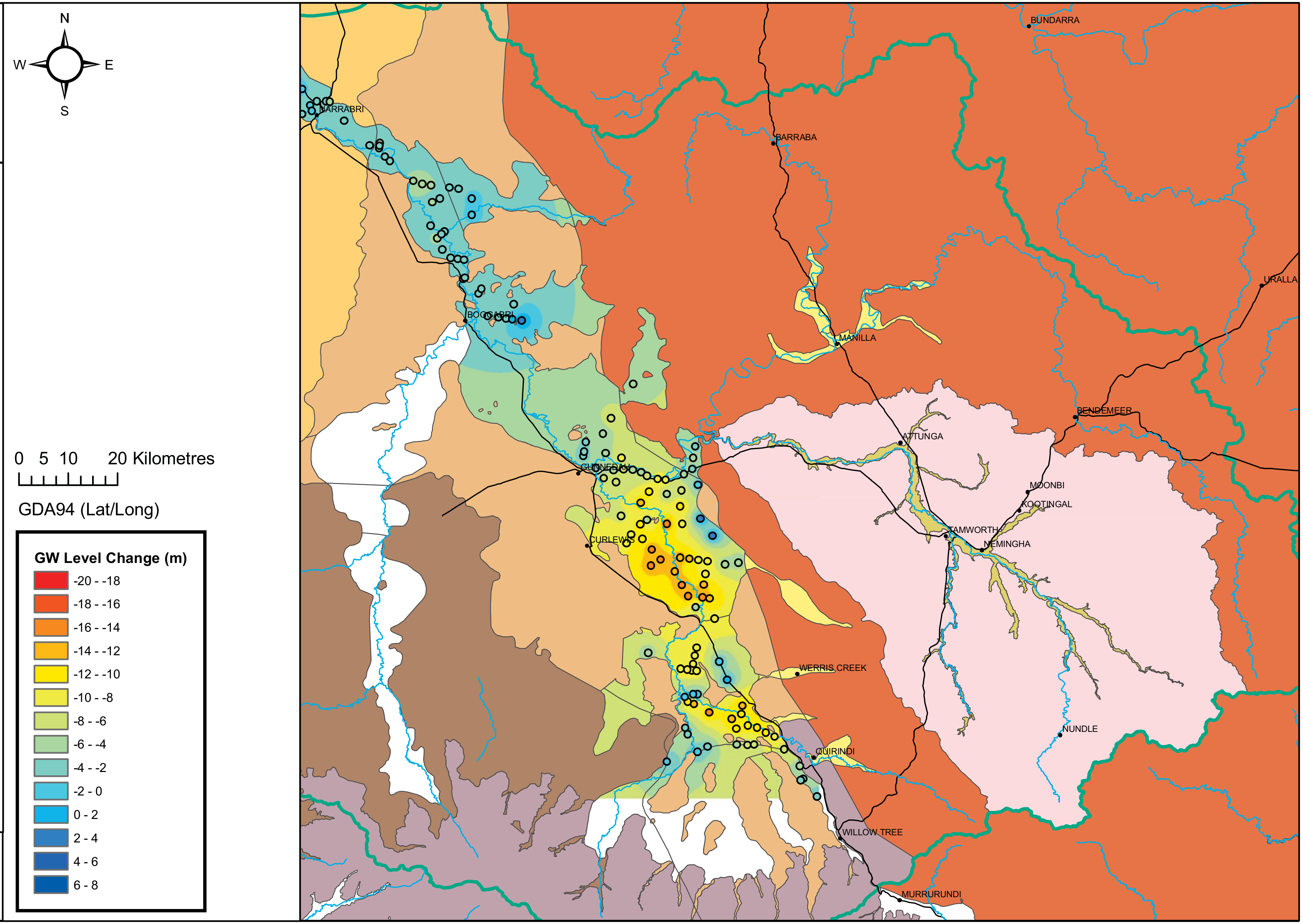


Figure 51

Namoi_4_4.mxd

WRL

Report No. 2009/25

GROUNDWATER LEVEL CHANGE 1978-2006 (RECOVERED)
UPPER MONITORING UNIT, UPPER NAMOI - ZONE 3

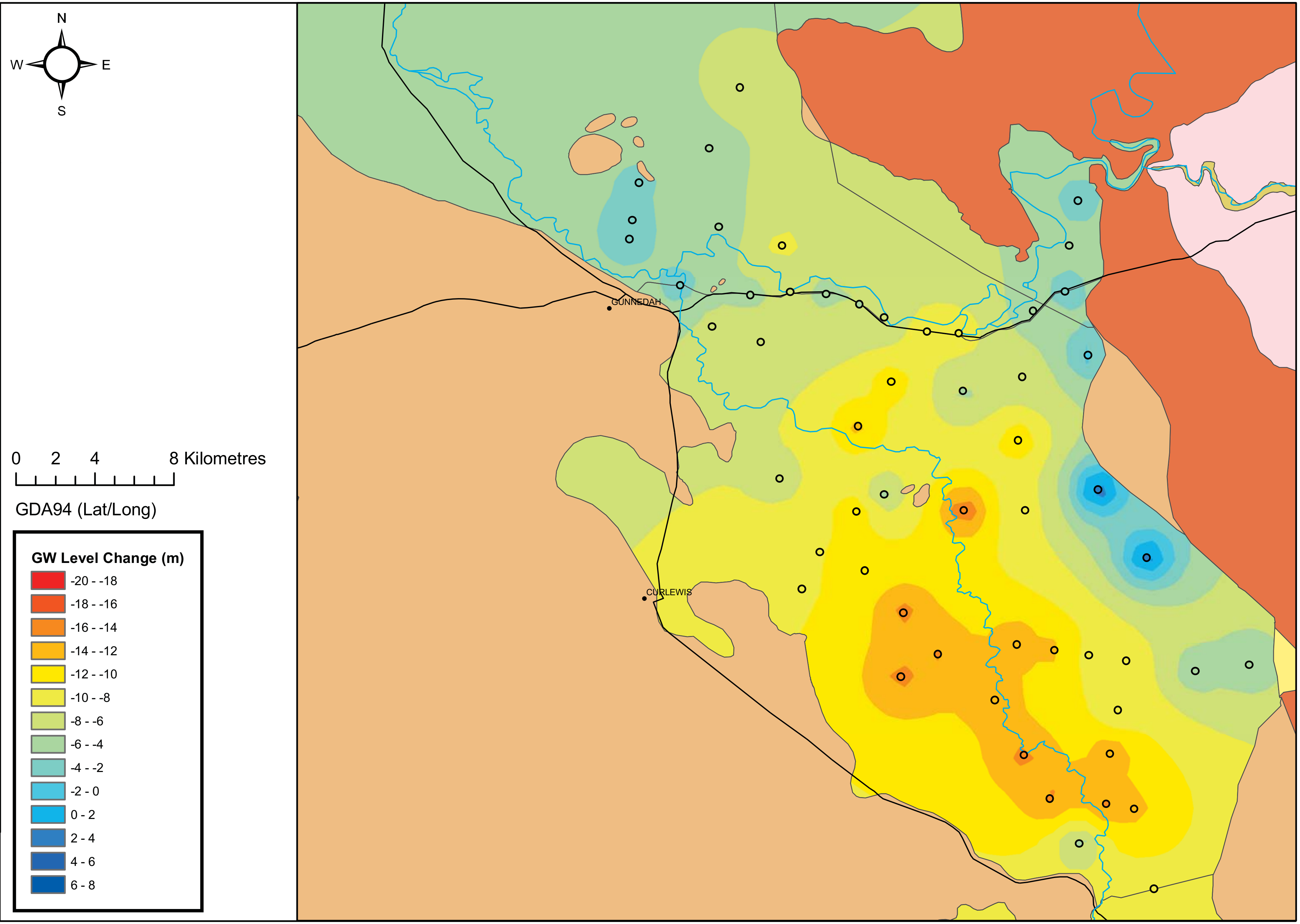


Figure 52

Namoi_4_4.mxd

WRL
Report No. 2009/25

GROUNDWATER LEVEL CHANGE 1978-2006 (RECOVERED)
UPPER MONITORING UNIT, LOWER NAMOI

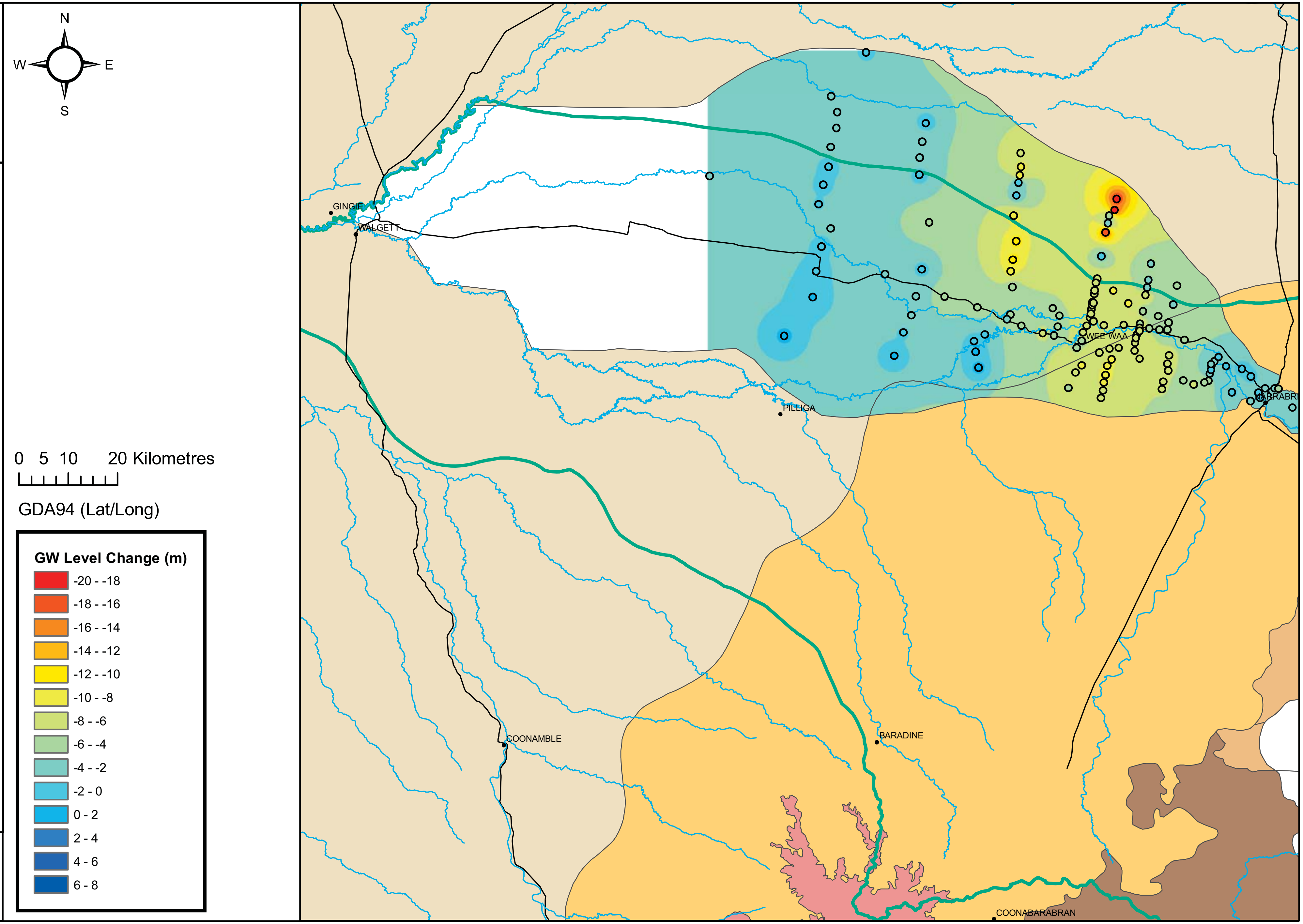


Figure
53

Namoi_4_4.mxd

WRL

Report No. 2009/25

GROUNDWATER LEVEL CHANGE 1988-2006 (RECOVERED)
UPPER MONITORING UNIT, UPPER NAMOI

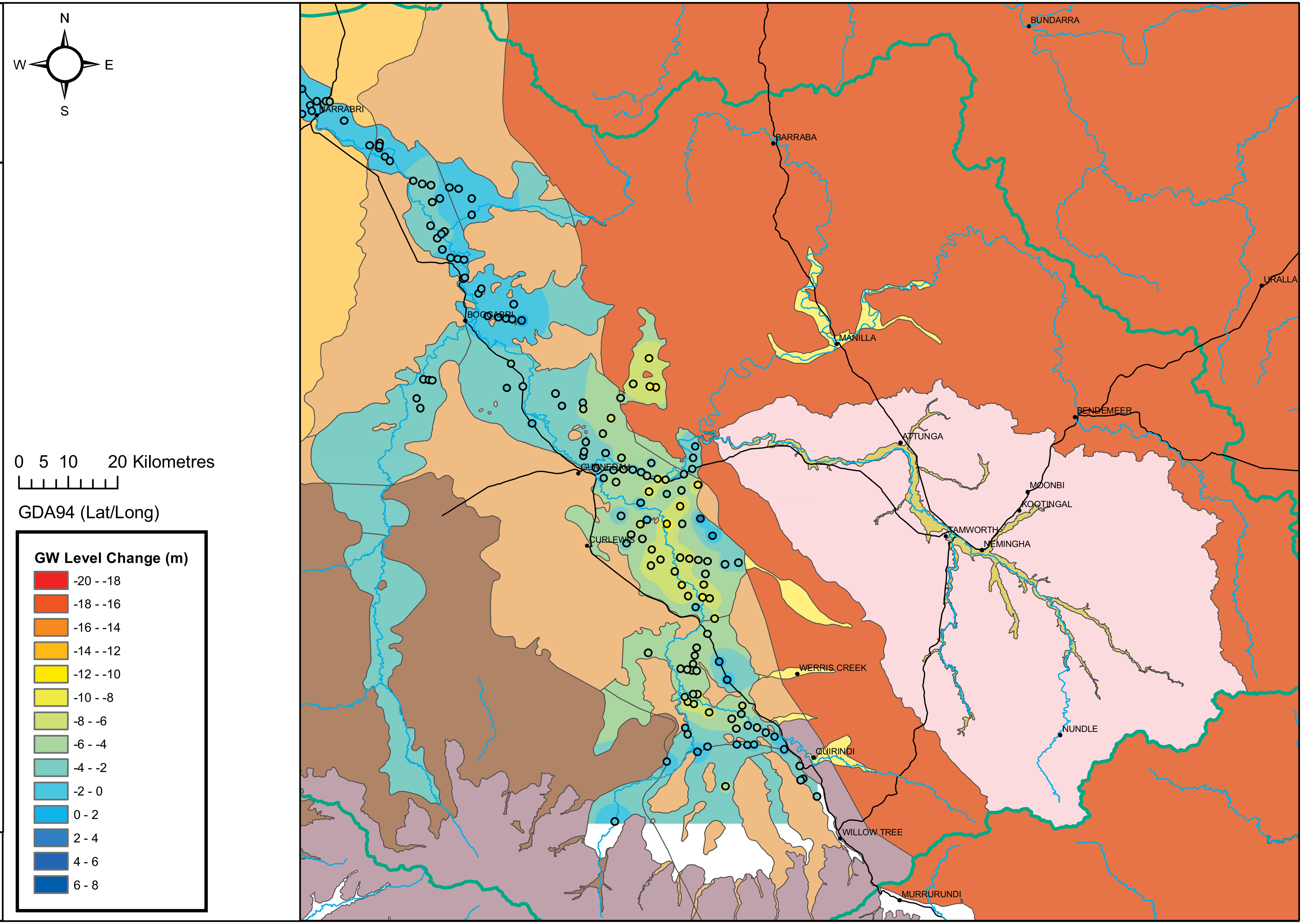


Figure
54

Namoi_4_13.mxd

WRL

Report No. 2009/25

GROUNDWATER LEVEL CHANGE 1978-2006 (RECOVERED)
LOWER MONITORING UNIT, UPPER NAMOI

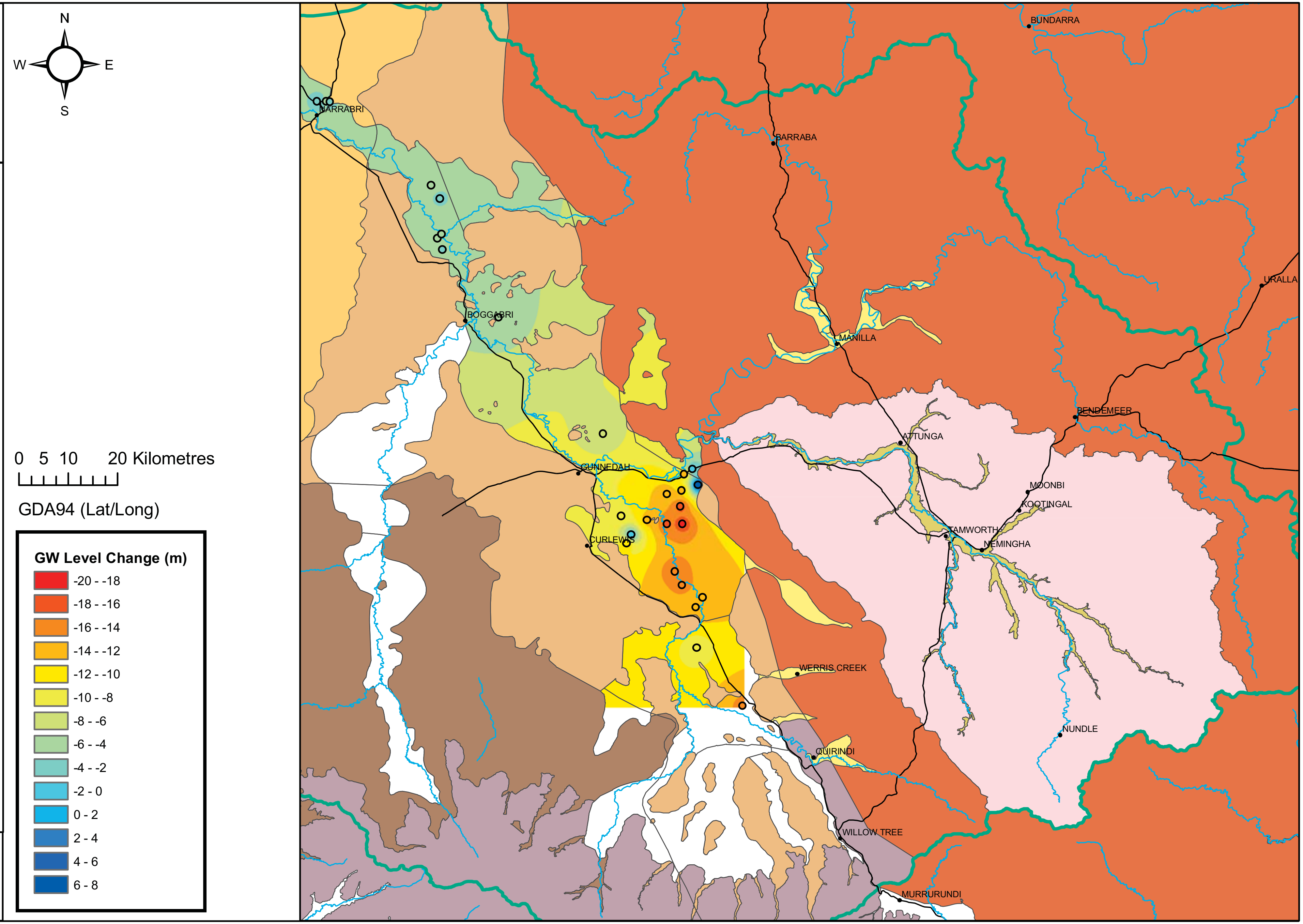


Figure 55

Namoi_4_4.mxd

WRL
Report No. 2009/25

GROUNDWATER LEVEL CHANGE 1978-2006 (RECOVERED)
LOWER MONITORING UNIT, UPPER NAMOI - ZONE 3

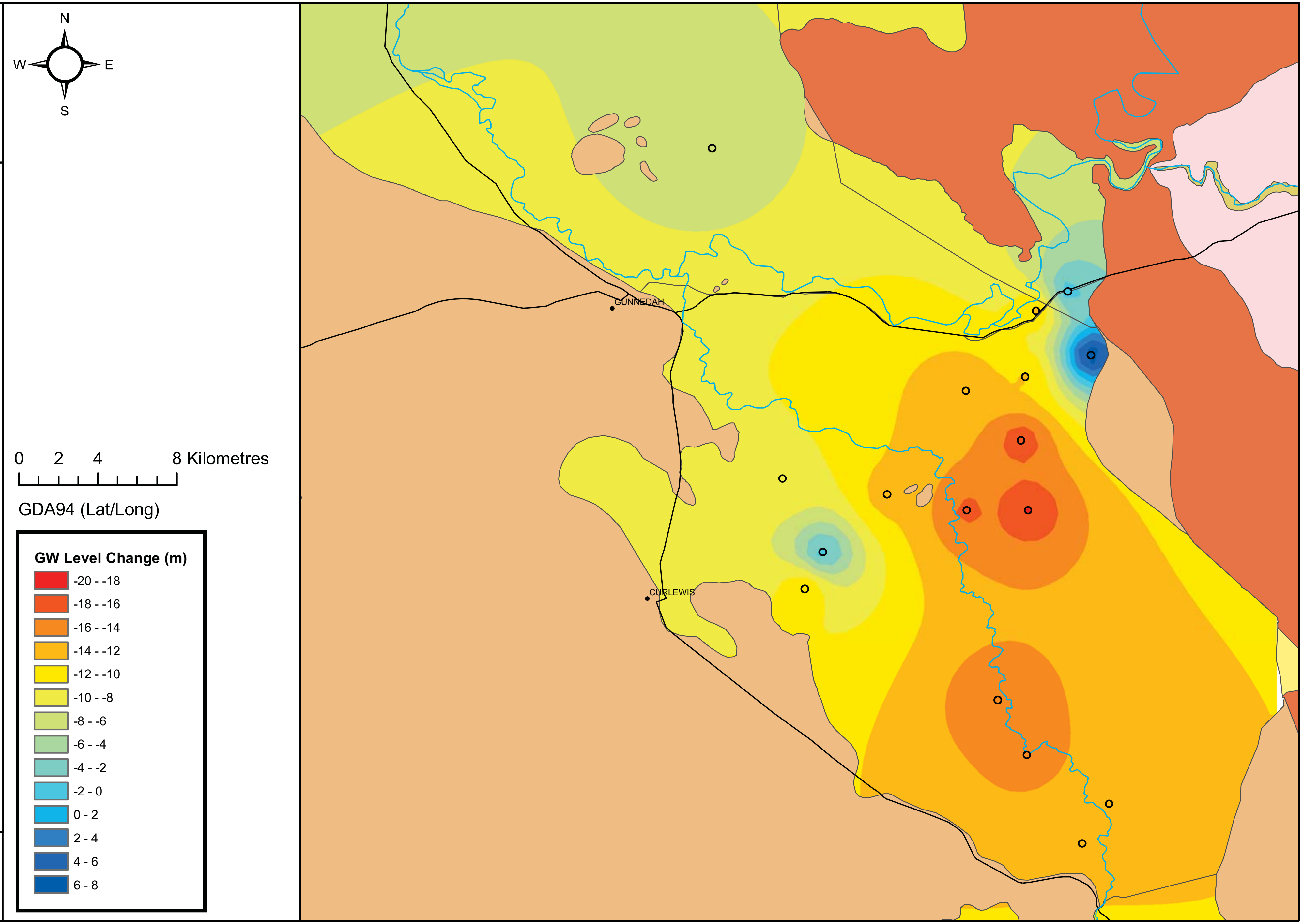


Figure 56

Namoi_4_4.mxd

WRL
Report No. 2009/25

GROUNDWATER LEVEL CHANGE 1978-2006 (RECOVERED)
LOWER MONITORING UNIT, LOWER NAMOI

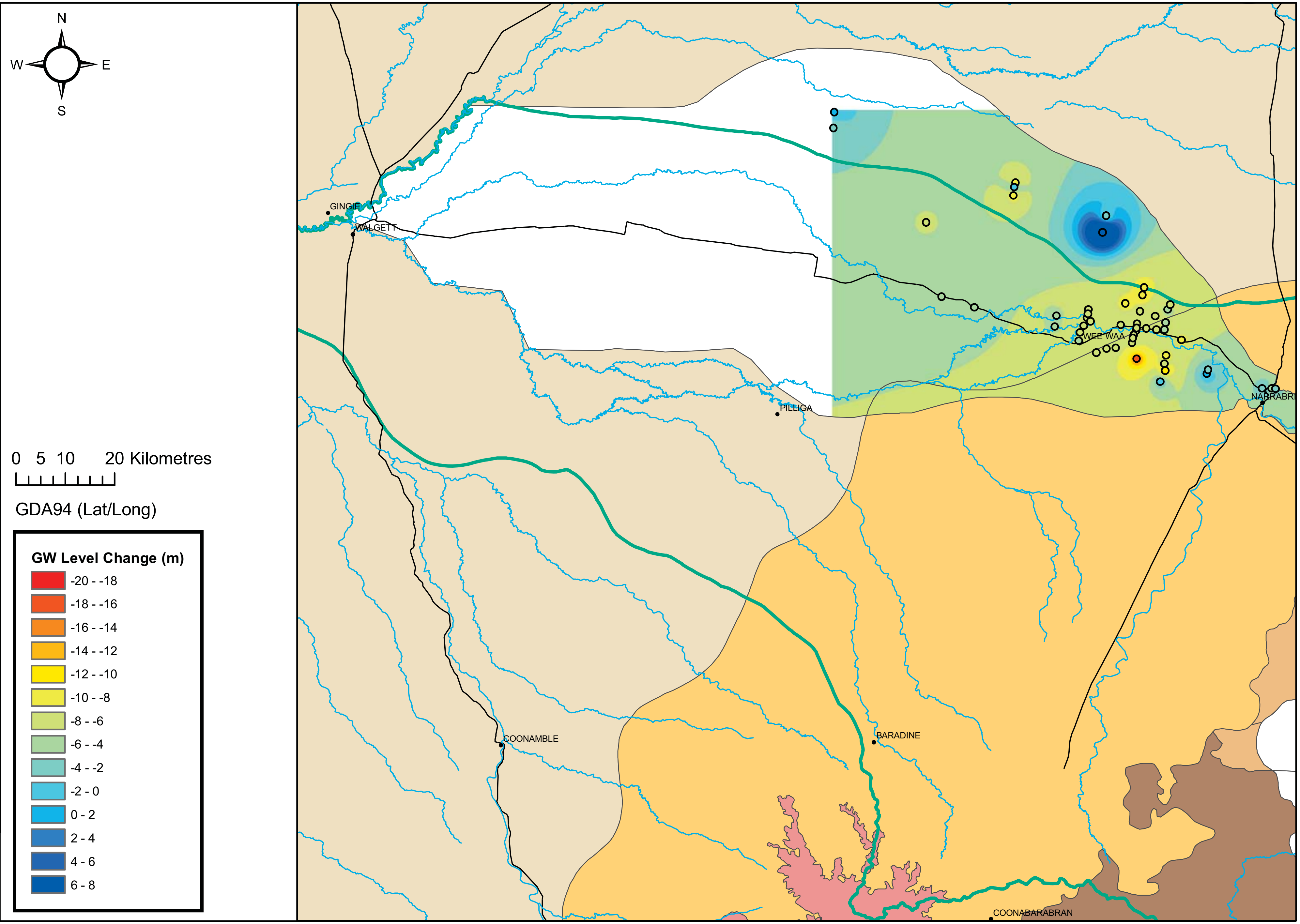


Figure
57

Namoi_4_4.mxd

WRL
Report No. 2009/25

GROUNDWATER LEVEL CHANGE 1988-2006 (RECOVERED)
LOWER MONITORING UNIT, UPPER NAMOI

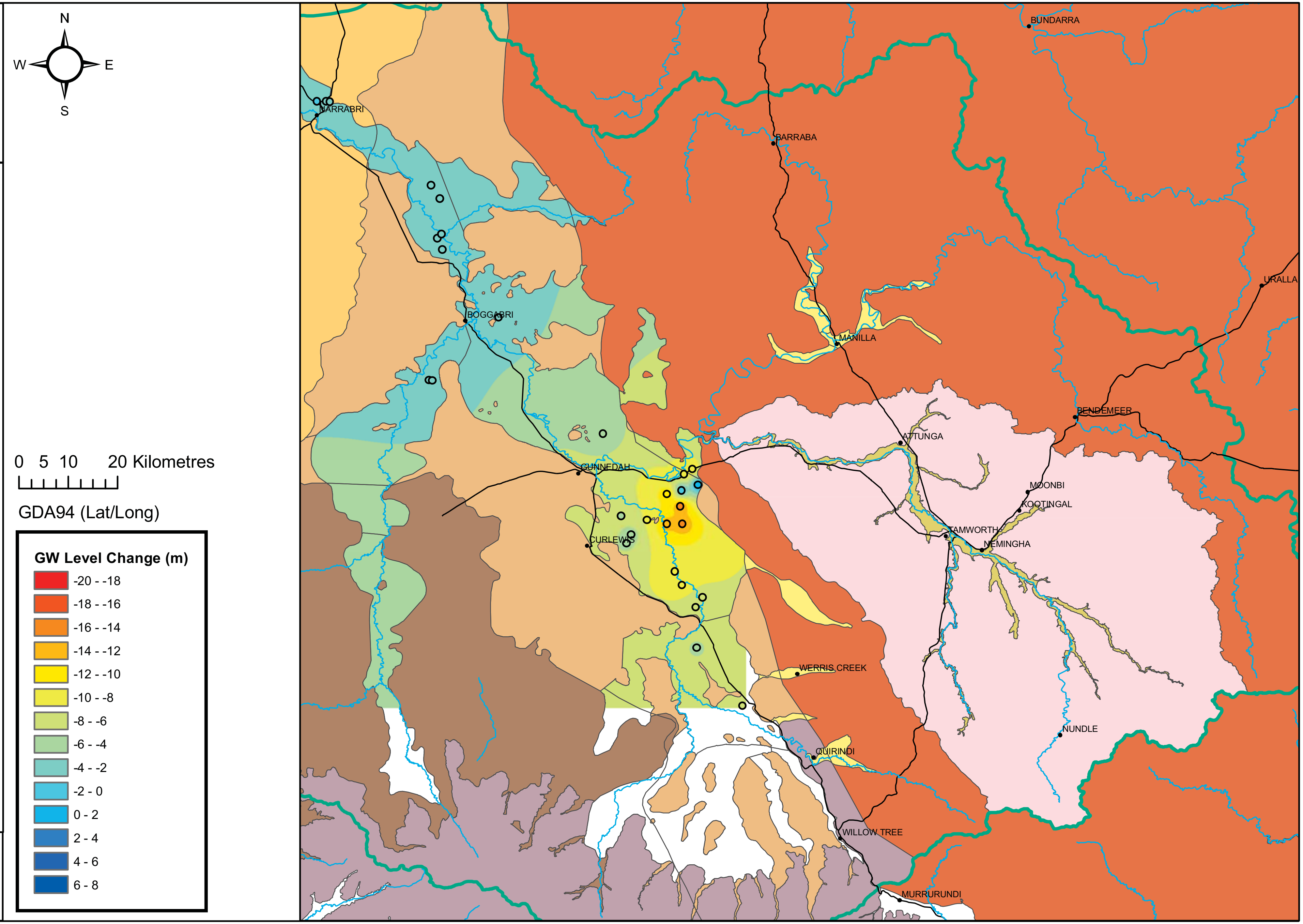


Figure
58

Namoi_4_13.mxd

GROUNDWATER LEVEL CHANGE 2006-2008 (RECOVERED)
UPPER MONITORING UNIT, UPPER NAMOI

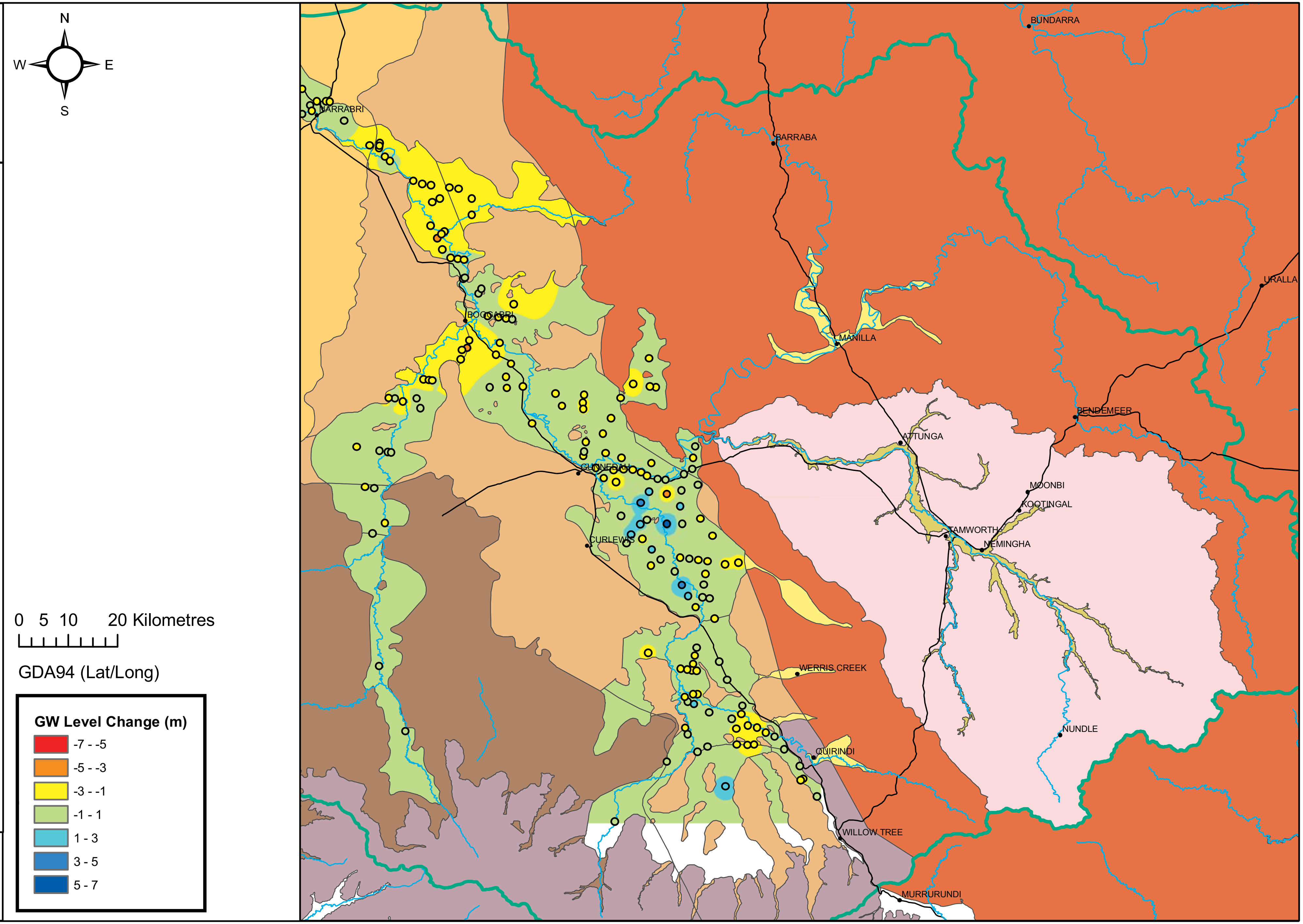


Figure
59

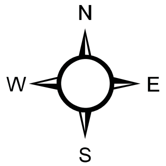
WRL

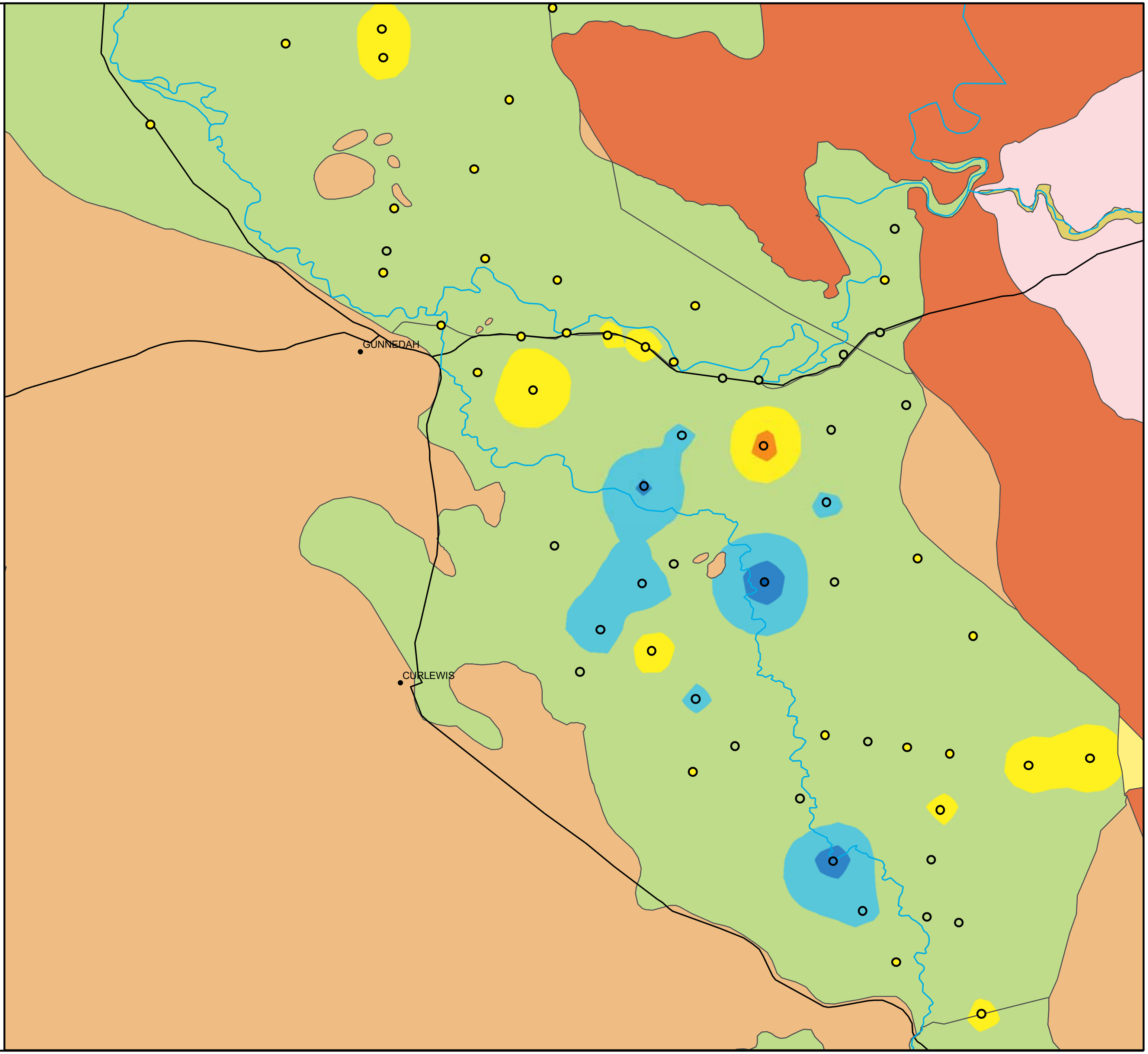
Report No. 2009/25

GROUNDWATER LEVEL CHANGE 2006-2008 (RECOVERED)
UPPER MONITORING UNIT, UPPER NAMOI - ZONE 3

Figure
60

Namoi_4_6.mxd





0 2 4 8 Kilometres

GDA94 (Lat/Long)

GW Level Change (m)

- -7 - -5
- -5 - -3
- -3 - -1
- -1 - 1
- 1 - 3
- 3 - 5
- 5 - 7

WRL

Report No. 2009/25

GROUNDWATER LEVEL CHANGE 2006-2008 (RECOVERED)
UPPER MONITORING UNIT, LOWER NAMOI

Figure 61

Namoi_4_6.mxd

N

W E

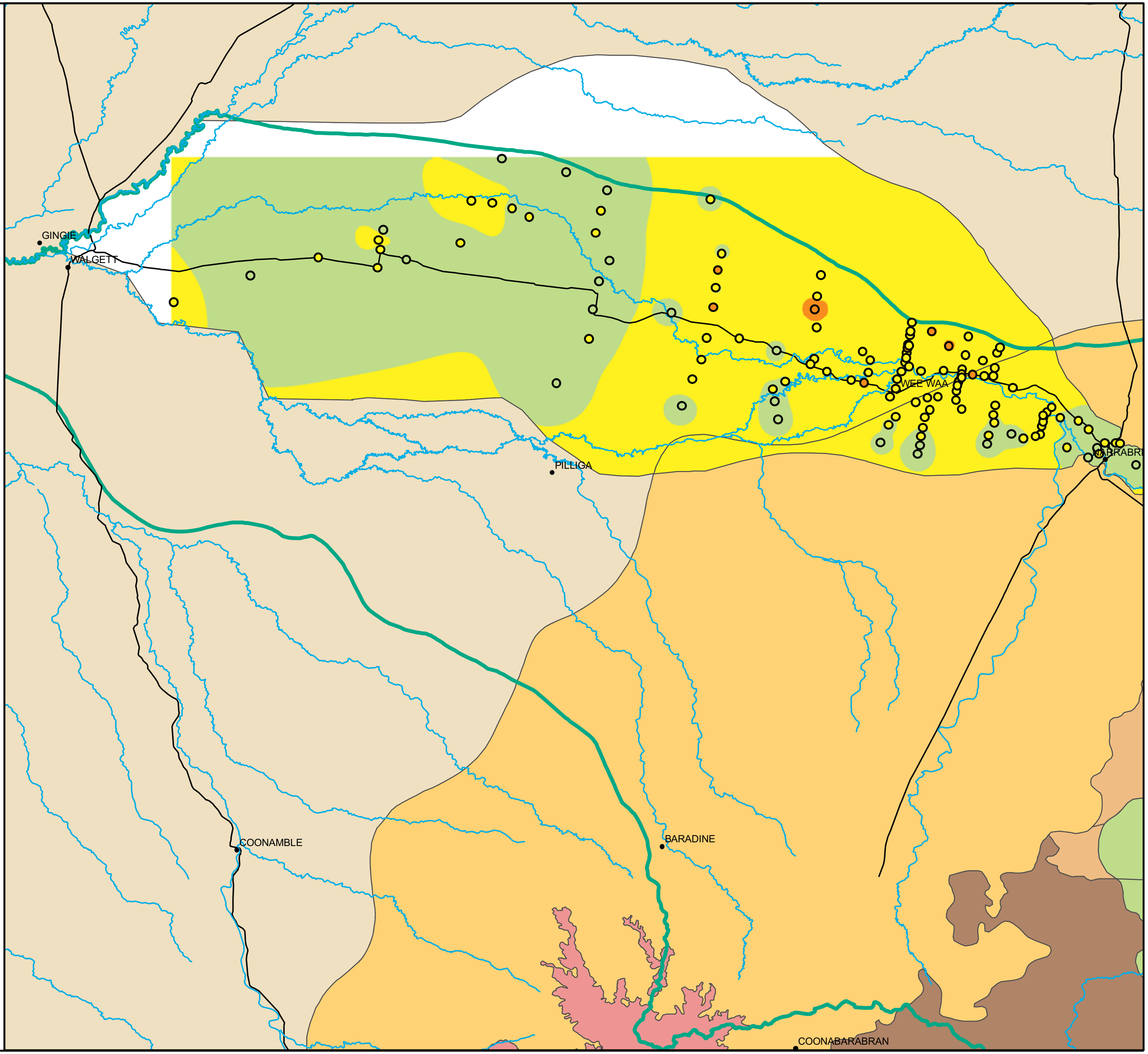
S

0 5 10 20 Kilometres

GDA94 (Lat/Long)

GW Level Change (m)

- -7 - -5
- -5 - -3
- -3 - -1
- -1 - 1
- 1 - 3
- 3 - 5
- 5 - 7



WRL

Report No. 2009/25

GROUNDWATER LEVEL CHANGE 2006-2008 (RECOVERED)
LOWER MONITORING UNIT, UPPER NAMOI

N
W E
S

0 5 10 20 Kilometres

GDA94 (Lat/Long)

GW Level Change (m)

- -7 - -5
- -5 - -3
- -3 - -1
- -1 - 1
- 1 - 3
- 3 - 5
- 5 - 7

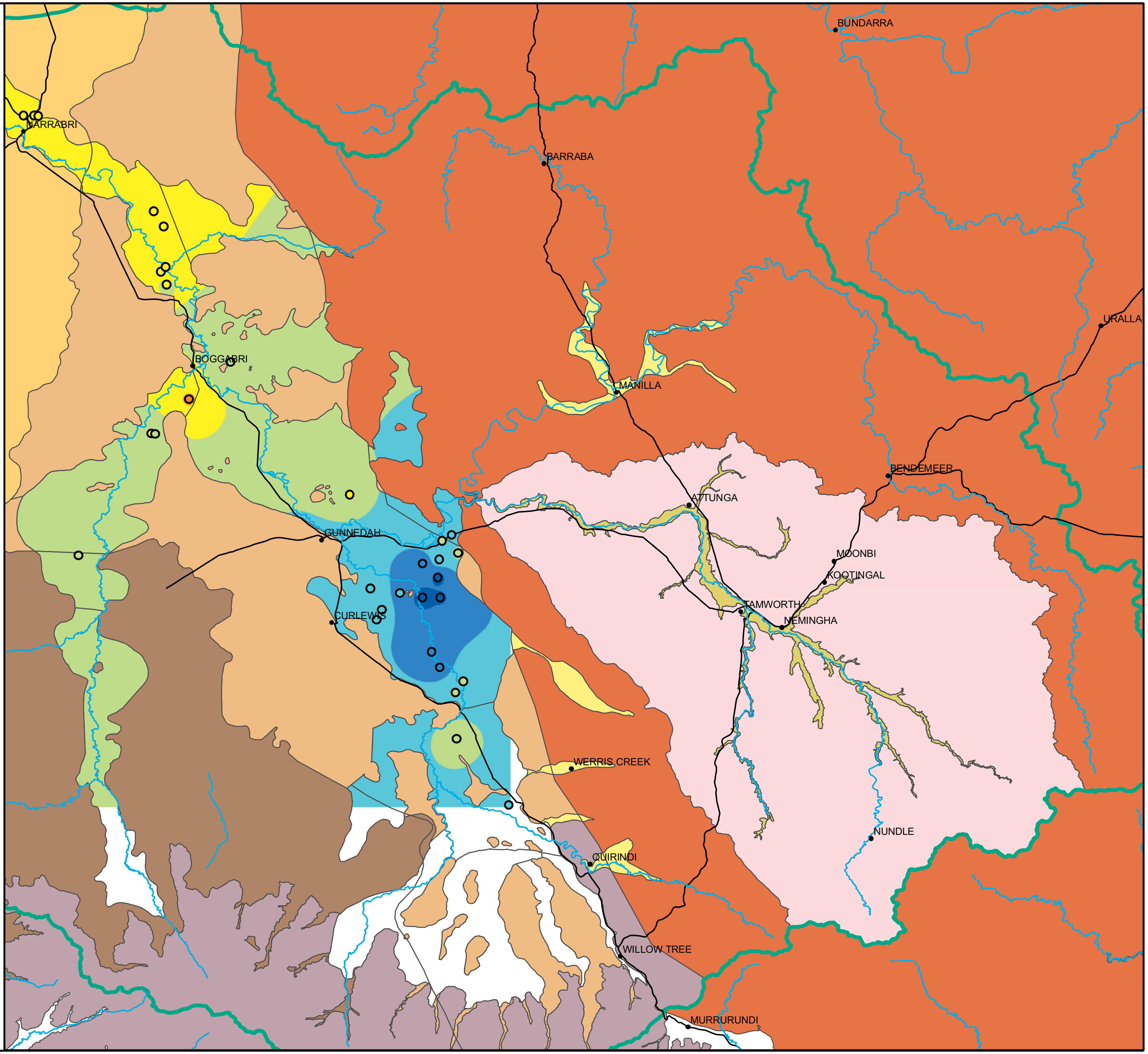


Figure 62

Namoi_4_6.mxd

WRL

Report No. 2009/25

GROUNDWATER LEVEL CHANGE 2006-2008 (RECOVERED)
LOWER MONITORING UNIT, UPPER NAMOI - ZONE 3

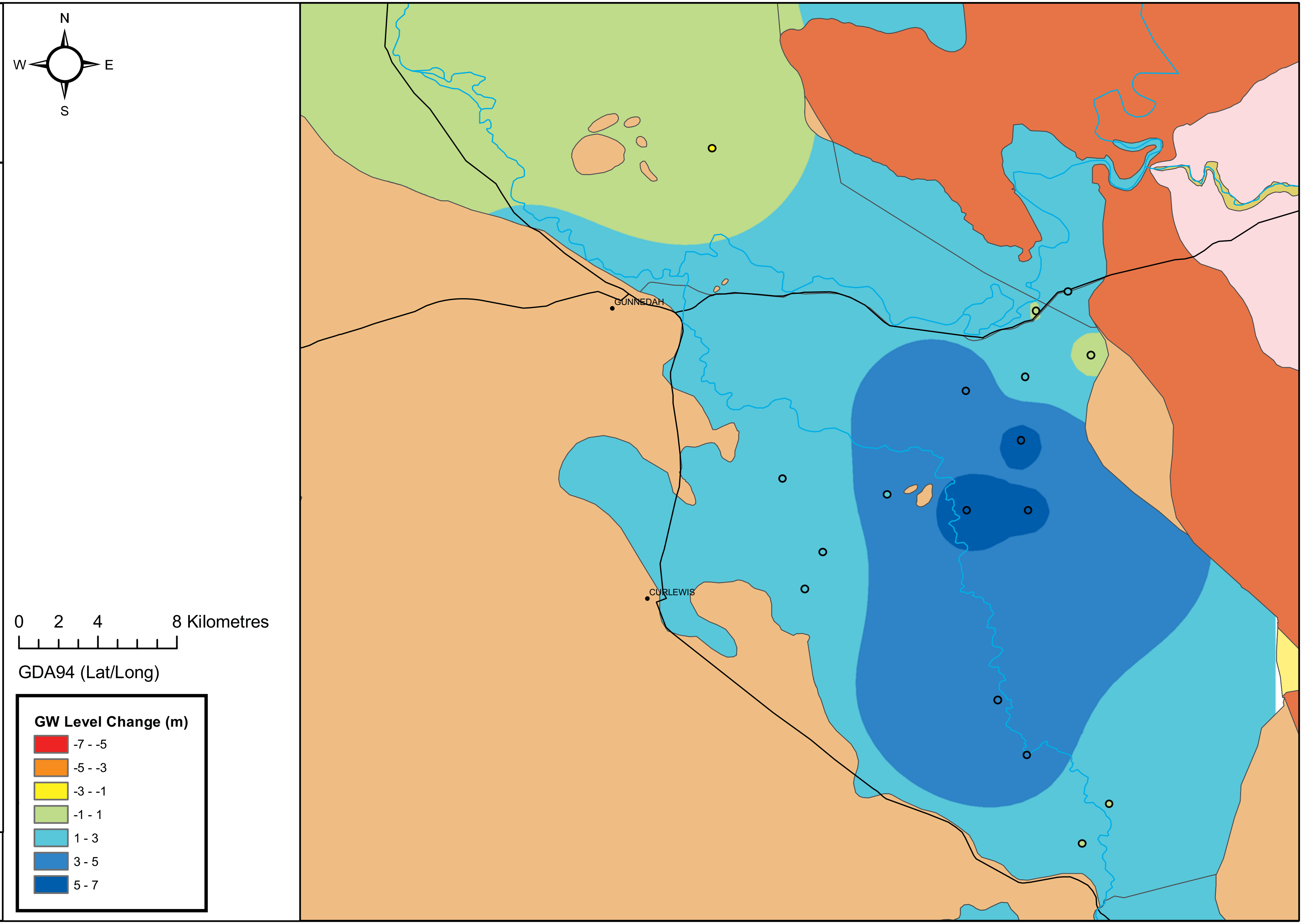


Figure 63

Namoi_4_6.mxd

WRL

Report No. 2009/25

GROUNDWATER LEVEL CHANGE 2006-2008 (RECOVERED)
LOWER MONITORING UNIT, LOWER NAMOI

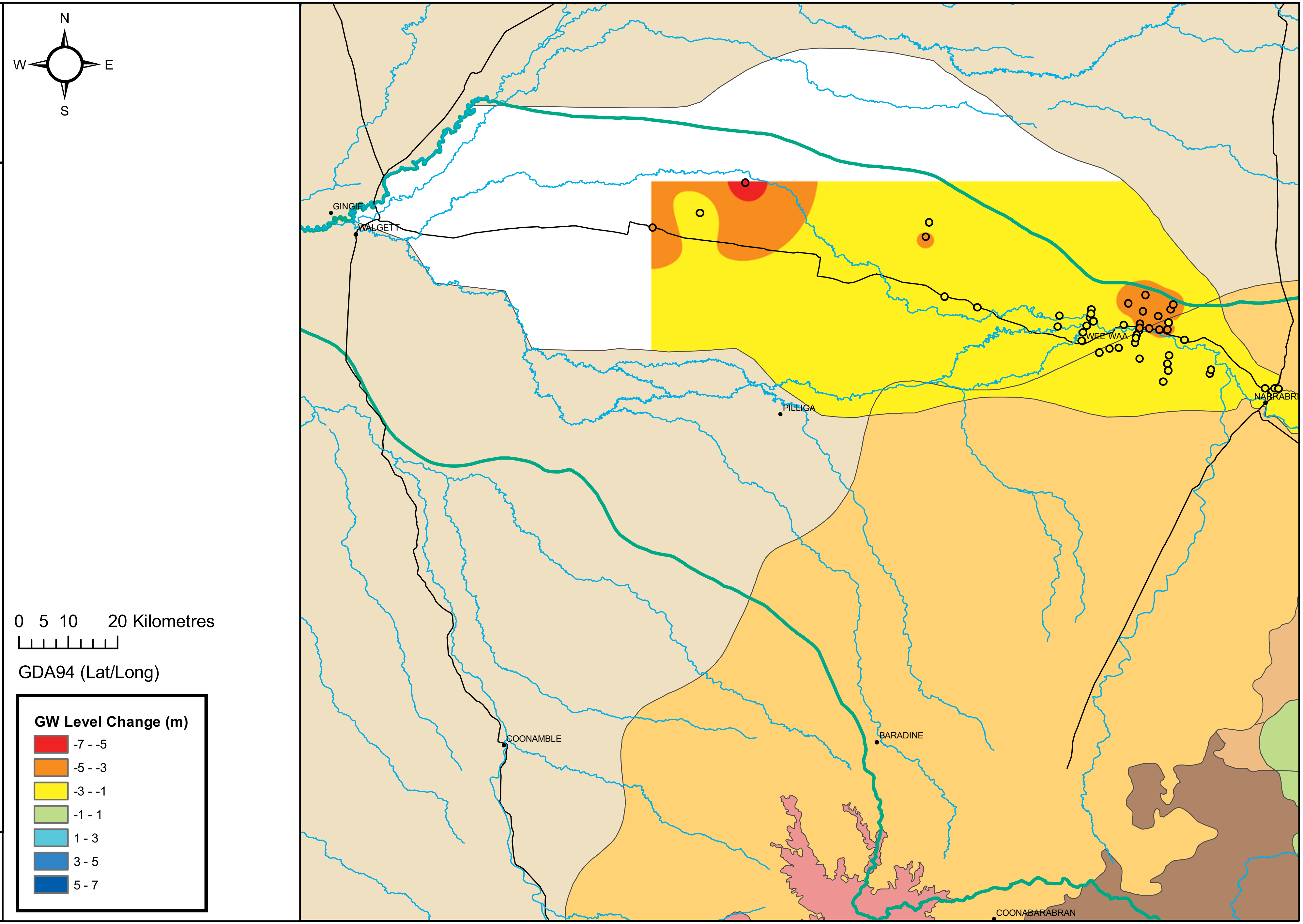
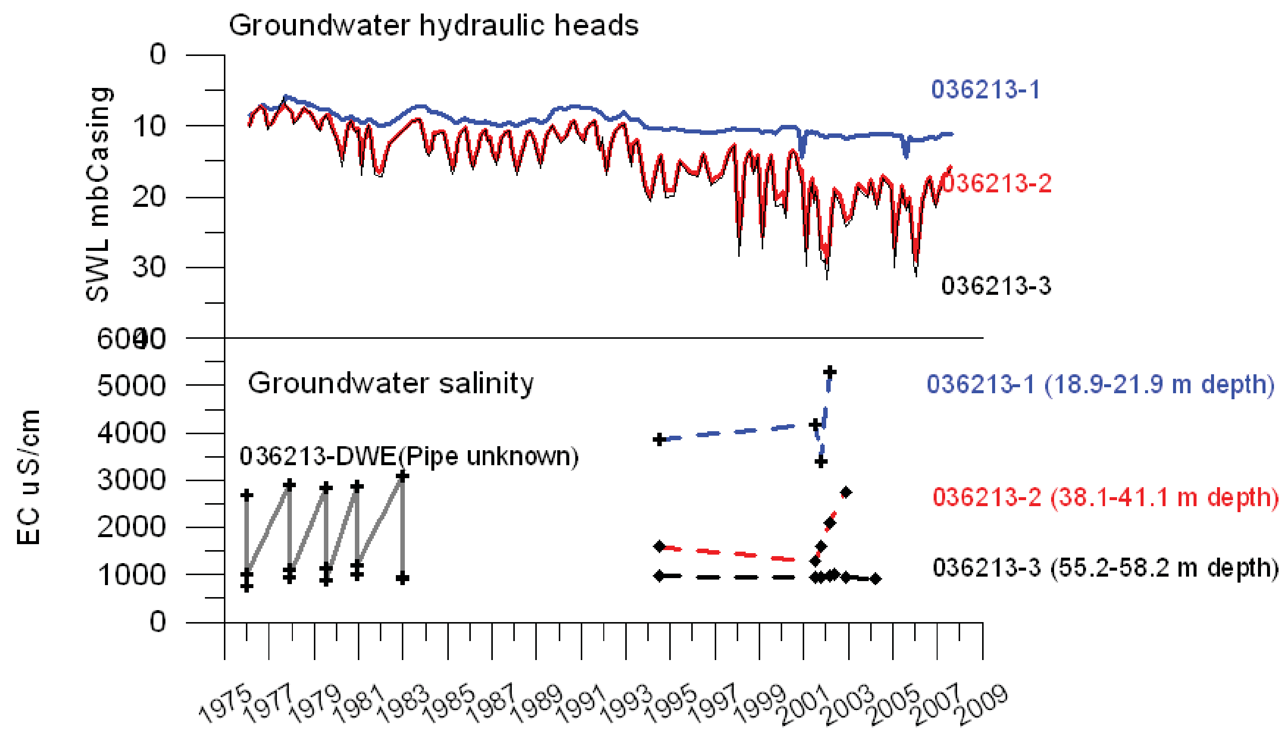
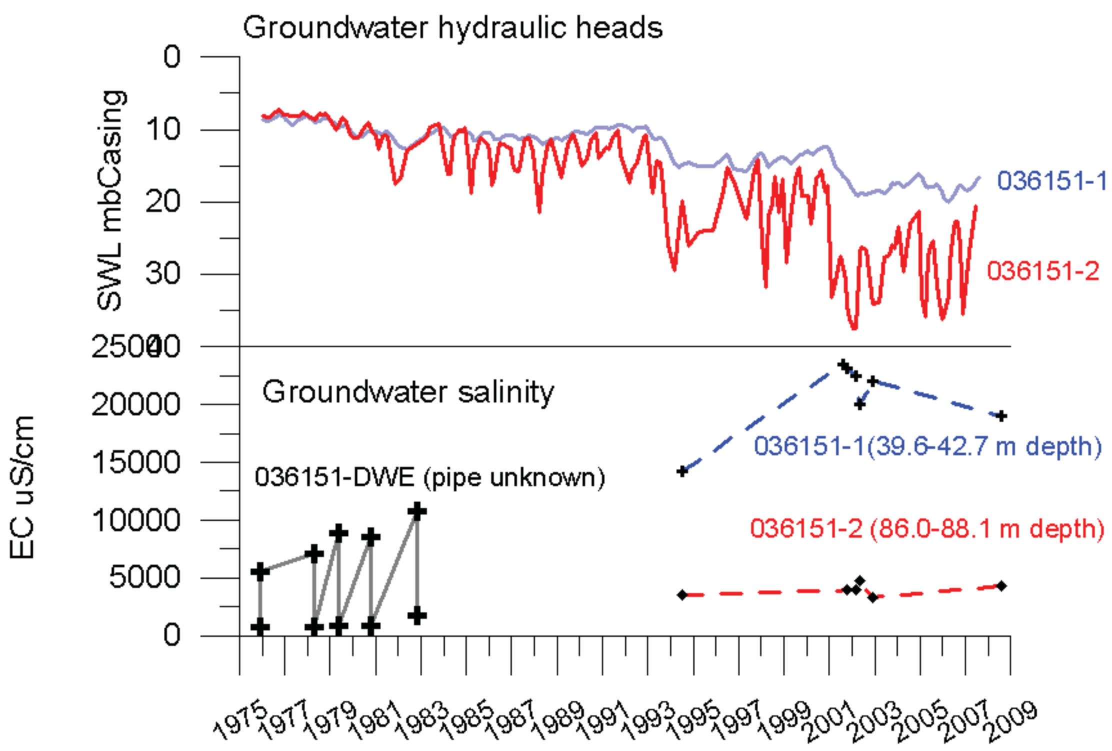


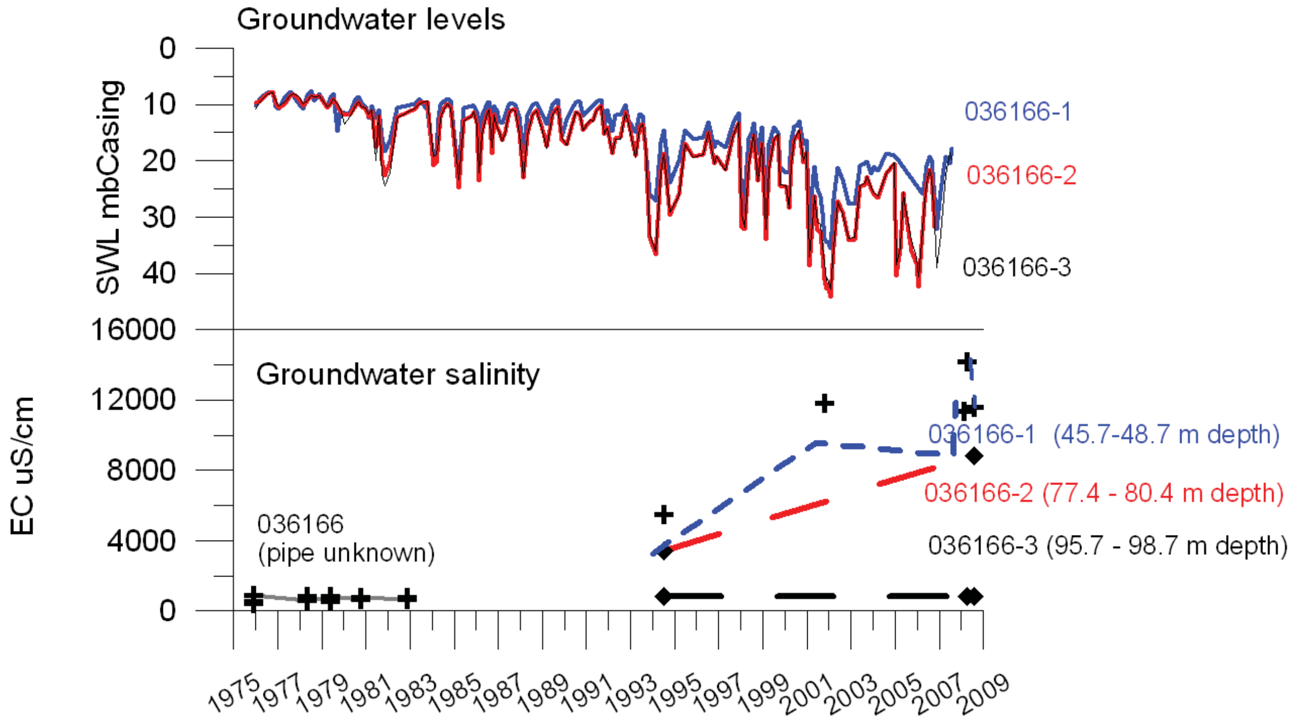
Figure 64

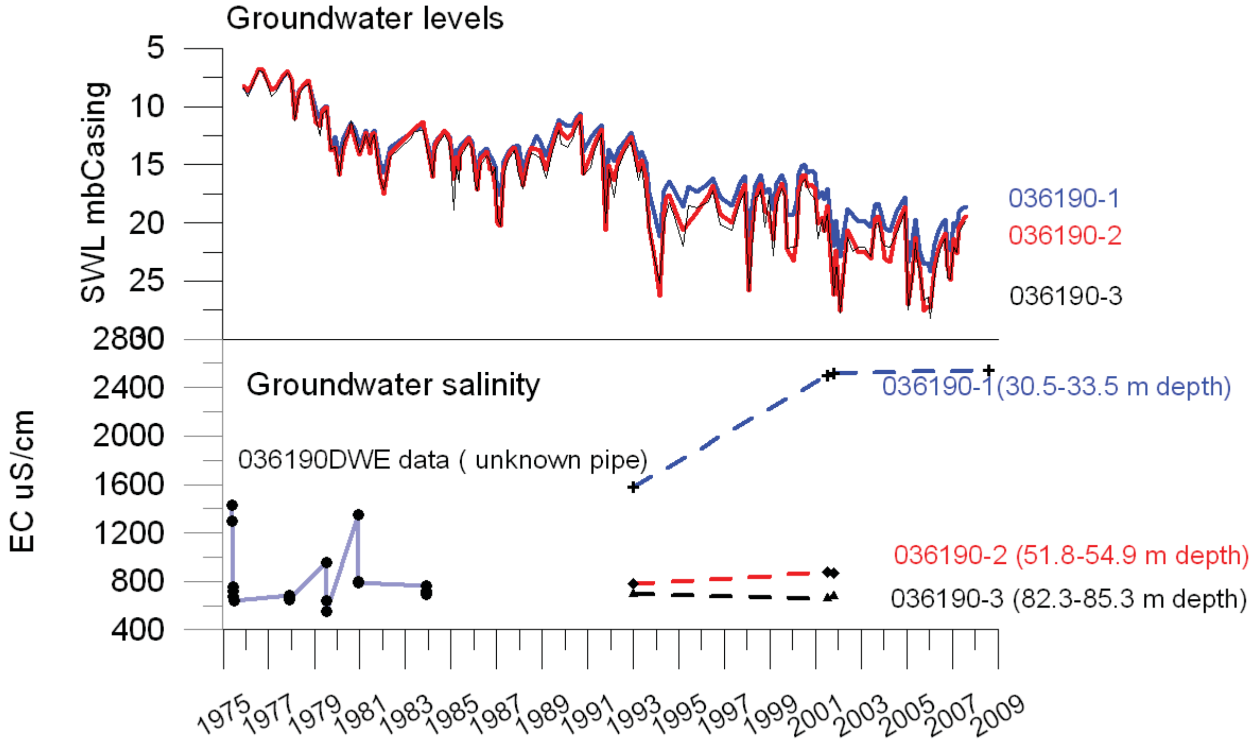
Namoi_4_6.mxd



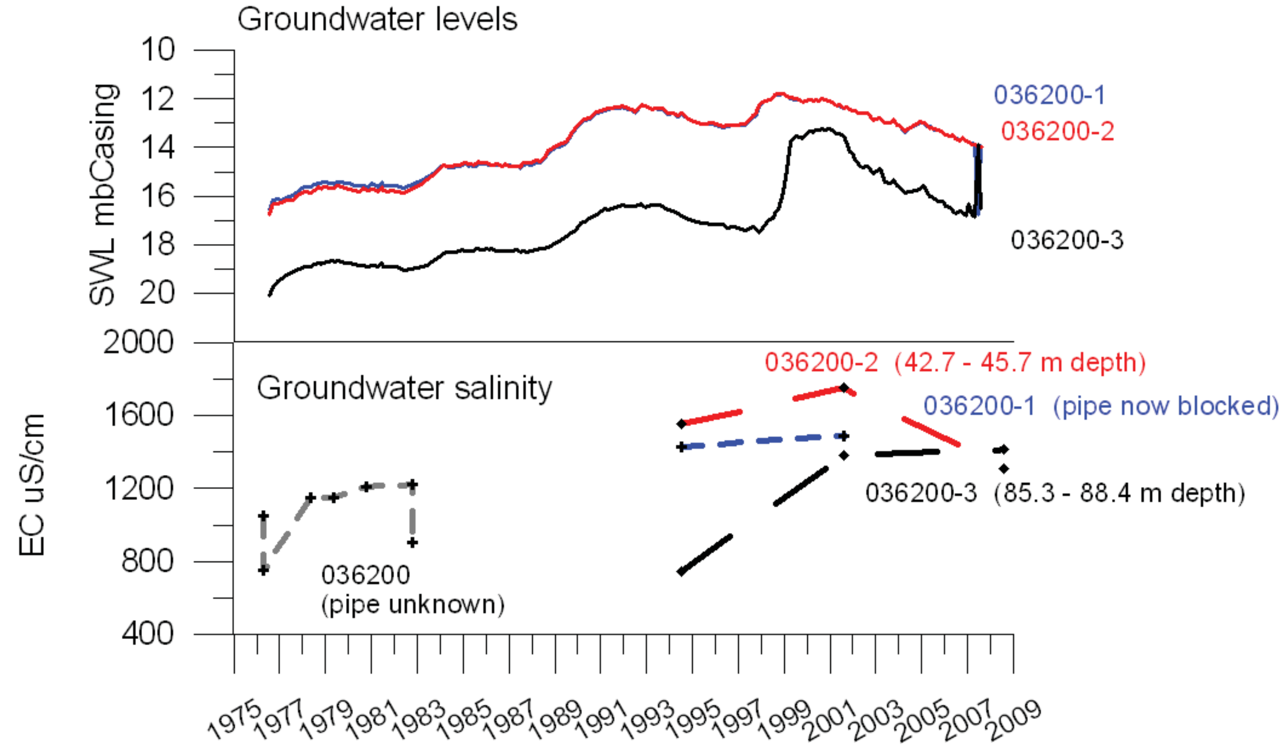


WRL Report No. 2009/25	HISTORICAL WATER LEVEL AND SALINITY DATA GW036213 & GW036151	Figure 65

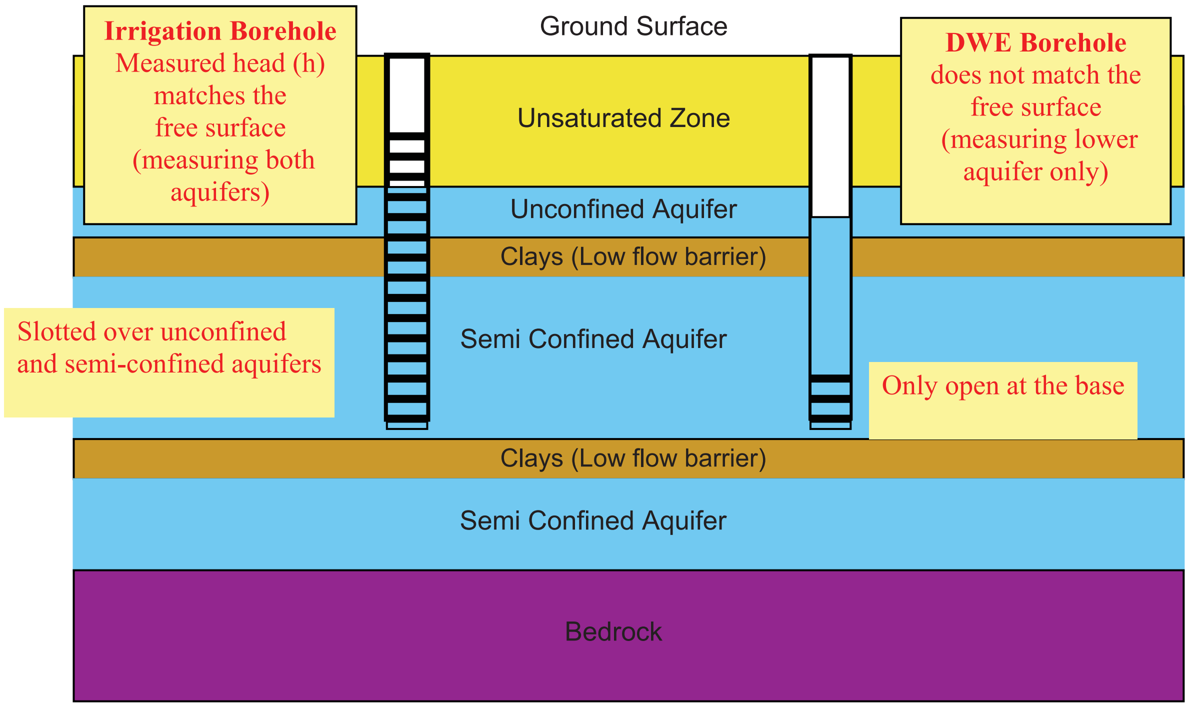




WRL Report No. 2009/25	HISTORICAL WATER LEVEL AND SALINITY DATA GW036166 & GW036190	Figure 66



WRL Report No. 2009/25	HISTORICAL WATER LEVEL AND SALINITY DATA GW036200	Figure 67



Courtesy of Bryce Kelly

WRL Report No. 2009/25

HISTORICAL EC OF EXAMPLE BORES SHOWING MANN KENDALL TRENDS

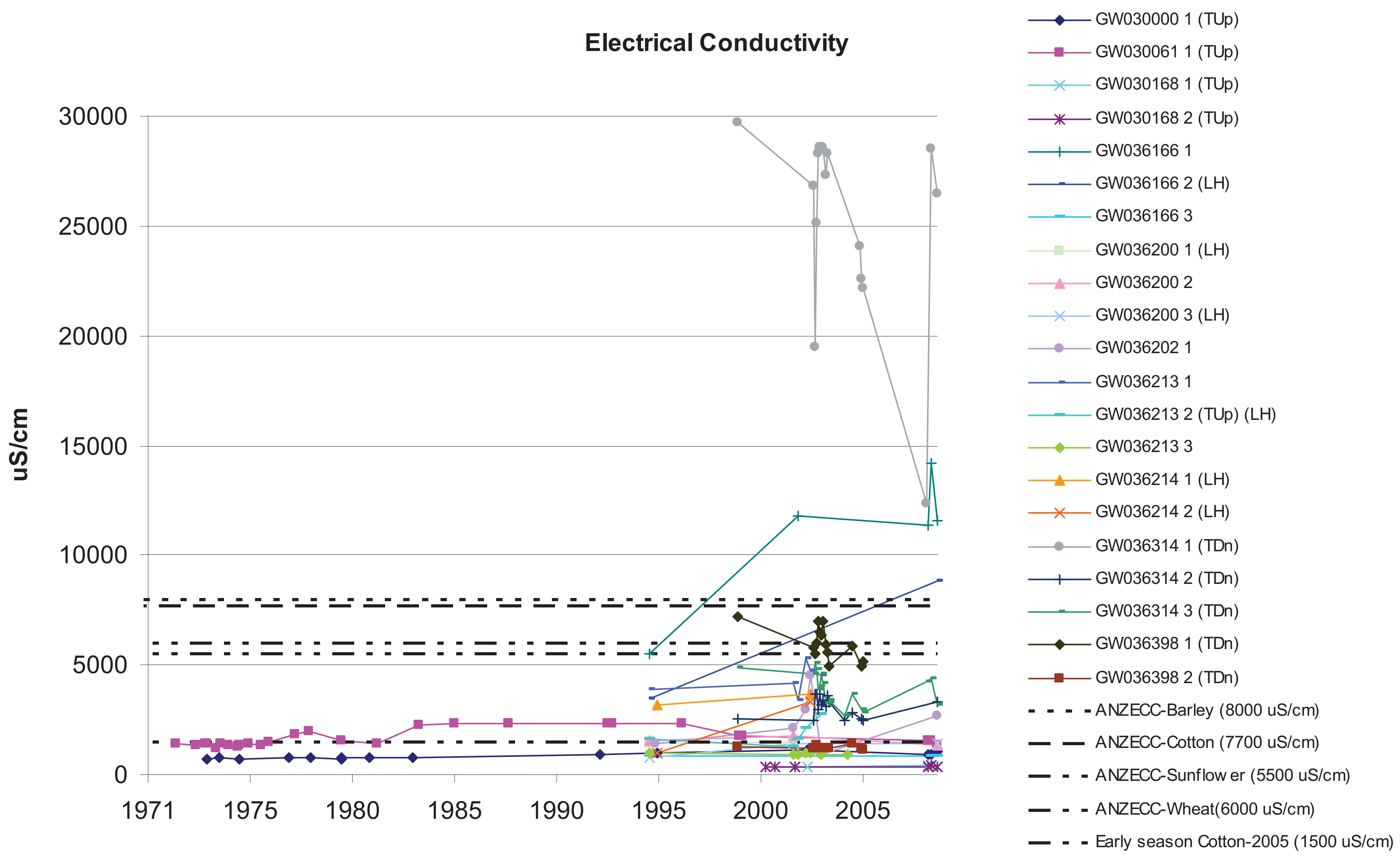


Figure 69

APPENDIX A1
STATISTICAL TECHNIQUES FOR DATA ANALYSIS

APPENDIX A1

Mean

The most commonly used measure of the centre of a sample is the sample mean, denoted by *X*. This estimate of the centre of a sample can be thought of as the "centre of gravity" of the sample. The sample mean is an arithmetic average for simple sampling designs; however, for complex sampling designs, such as stratification, the sample mean is a weighted arithmetic average. While the mean is often used to report central tendency it is not a robust statistic, meaning that it is greatly influenced by outliers.

Variance and Standard Deviation

The variance measures the dispersion of the data from the mean and is denoted by s^2. A large variance implies that there is a large spread among the data so that the data are not clustered around the mean. A small variance implies that there is little spread among the data so that most of the data are near the mean. The variance is affected by extreme values and by a large number of non-detects. The standard deviation (s) is the square root of the sample variance and has the same unit of measure as the data. Standard deviation is also a measure of the variability or dispersion of a statistical population, a data set, or a probability distribution. A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data are spread out over a large range of values.

Statistical Prediction Intervals-Single Location and Constituent

If the problem were to set a 100% limit on the next single measurement for one location and one normally distributed constituent, a b-expectation tolerance limit (i.e., a prediction limit — Guttman, 1970; Hahn, 1970) could be computed from n independent background measurements as

$$\mathbf{PI} = \bar{x} + t_{(n-1,1-\alpha)} s \sqrt{1 + \frac{1}{n}}$$

where concern is that the concentration is elevated above background, x and s are the background sample mean and standard deviation, respectively, and t is the 100(1 2a) percentile of Student's t-distribution on n 2 1 degrees of freedom. If upgradient versus downgradient comparisons are to be performed, then a minimum of two background locations (e.g., wells) should be repeatedly sampled at a time interval sufficient to ensure independence (e.g., quarterly or semi-annually).

The background time period must include at least 1 yr to ensure that the same seasonal variation present in down-gradient locations is rejected in the up-gradient background. The reader should note that with multiple up-gradient locations, s^2, the traditional estimator of σ^2 is biased (i.e., it is too small) because measurements are nested within up-gradient monitoring locations. Alternative estimators for s 2 based on variance components models have been proposed and should be used where appropriate (Sara and Gibbons, 2006).

Mann-Kendall tests

Mann-Kendall tests are non-parametric tests for the detection of trend in a time series. The test measures the similarity of the mean values for two samples; when applied to a subset of a times series data set, the test determines if there is a statistically meaningful drift in the mean value with respect to time. These tests are widely used in environmental science, because they are simple, robust and can cope with missing values and values below a detection limit. Since the first proposals of the test by Mann (1945) and Kendall (1975), covariances between Mann-Kendall statistics were proposed by Dietz and Kileen (1981) and the test was extended in order to include seasonality (Hirsch and Slack, 1982), multiple monitoring sites (Lettenmaier, 1988) and covariates representing natural fluctuations (Libiseller and Grimvall, 2002).

The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (*e.g.*, no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S.

Let 1 x , 2 x , … n x represent n data points where x_j represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

$$\begin{aligned} sign(x_j - x_k) &= 1 \text{ if } x_j - x_k > 0 \\ &= 0 \text{ if } x_j - x_k = 0 \\ &= \text{-}1 \text{ if } x_j - x_k < 0 \end{aligned}$$

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend (Hydrogeologic, Inc., 2005).

Statistical Error Types

Type I error, also known as a "false positive" is the error of rejecting a null hypothesis when it is actually true. In other words, it occurs when we are observing an exceedence when in truth there is none.

Type II error, also known as a "false negative" is the error of failing to reject a null hypothesis when it is in fact not true. This is the error of failing to observe a difference when in reality there is one. Type II error can be viewed as the error of excessive skepticism.

From the Bayesian point of view, a type one error is one that looks at information that should not substantially change one's prior estimate of probability, but does. A type two error is that one looks at information which should change one's estimate, but does not.

		Actual Condition	
		significant increase	no significant increase
Test Result	Test shows a significant increase	True Positive	False Positive
	Test shows no significant increase	False Negative	True Negative

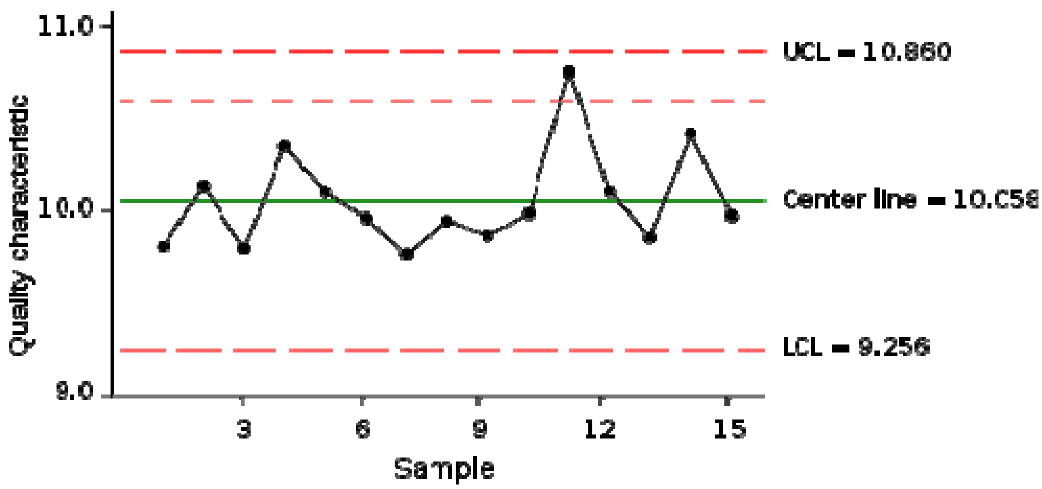
Control Chart

A control chart consists of:

- Points representing measurements of a quality characteristic in samples taken at different times [the data]
- A center line, drawn at the characteristic mean, which is calculated from the data
- Upper and lower control limits (sometimes called "natural limits") that indicate the threshold at which the output is considered statistically 'unlikely'

It may have other optional features, including:

- Upper and lower warning limits (UCL and LCL), drawn as separate lines, typically two standard deviations above and below the center line
- Division into zones, with the addition of rules governing frequencies of observations in each zone
- Annotation with events of interest, as determined by the Project Engineer



If water quality is stable, all points will plot within the control limits. Any observations outside the limits, or systematic patterns within, suggest the introduction of a new (and likely unanticipated) source of variation. Increased variation may trigger a review of data and groundwater management action.

Source: Shewhart (1939) Statistical Method from the Viewpoint of Quality Control.

APPENDIX A2
CONNECTIVITY METHOD OF DEFINING MONITORING UNITS

APPENDIX A2: CONNECTIVITY METHOD OF DEFINING MONITORING UNITS

Upper and lower monitoring units in the Namoi catchment have been traditionally defined according to depth (30 m). The thickness of the alluvium varies across the catchment and clay lenses have been identified as aquitards or semi confining layers in some areas. These characteristics result in different levels of connectivity (high to poor) among water baring bodies from various depths.

A method to distinguish between the upper and lower monitoring unit of the alluvium has been determined based on the connectivity of the resources, such that results of monitoring can be presented for the upper and lower monitoring units.

The connectivity of aquifers can be seen by comparing hydrographs between pipes at different depths in the same bore when the aquifer is under stress. The assumption is that the heads in two pipes should be the same, or approximately the same, (even when the aquifer is under stress) if they are well connected. Without stress, it is possible that two overlying monitoring units just happen to be similar. If the analysis is only required for a small number of bores, the connectivity between pipes can be examined simply by observing the graph, yet there still needs to be an objective means of delineating the difference between ‘Connected’ and ‘Poorly Connected’ layers where there is some doubt. Where there are many bores with many pipes (such as in the Namoi Catchment), there is value in being able to automate this process. There were two main ways considered to analyse the connectivity between overlying pipes:

- Comparing the recovered head levels between any two years
- Comparing the minimum and maximum head levels in any one year.

The second method was chosen as the aquifer under stress would give a better indication of connectivity, with the year 1986 chosen as a year when most of the catchment was monitored. Where the difference in head level was less than the determined threshold difference, the pipe was termed ‘connected’ to the pipe above it, whereas greater than this threshold, the pipes were termed ‘poorly connected’.

The automated analysis was completed using Python scripting, which firstly screened the data to remove data where:

- Skip the blanks i.e. those locations without ground surface m.a.s.l.
- Remove the GAB bores if depth >1000m

- Filter out extreme values (>50 m or <-50 m)
- Limit to bores with small opening range, i.e. piezometers <100m.

A sensitivity analysis was completed of appropriate threshold values to delineate between 'connected' and 'poorly connected'. There were 547 pipes with appropriate data to test. Table A2.1summarises the differences between using values ranging from 1 – 5 m, where each value was compared to the previous one i.e. if the cutoff value is changed from 3 m to 2 m 49 pipes would change from being considered "Connected" to the pipe above, to being considered "Poorly Connected". Overall, 29% of pipes changed connectivity value if the threshold value was altered between 1 – 5 m; conversely 71% of pipes did not change connectivity value regardless of the threshold value chosen. From this analysis, 3 m was chosen as a reasonable threshold value to use.

Table A2.1
Sensitivity Analysis of Changing Threshold Value for Connectivity Cutoff

5 m	4m	3m	2m	1m	ALL EQUAL
Connectivity unchanged	528	514	498	488	387
Connectivity Different from Previous	19	33	49	59	160
% Different from Previous	3	6	9	11	29

Assumptions and limitations inherent in this method at this time are listed below:

- The upper pipe is assumed to be intersecting the upper monitoring unit
- Analysis was only completed where accurate data was collected for the analysis year which limited the number of bores that could be presented
- A poorly installed monitoring bore may create a connection through all the monitoring units
- The analysis can't be completed where there is only one pipe.

A verification of the "Automated Designation" was completed using hydrographs for four selected boreholes. These hydrographs provide water level data from mid 1970s to 2006 for different pipes of each borehole. A visual comparison of fluctuation in these pipes (assuming potential periods of stress) can indicate the degree of connectivity between the related depths. For example, if the standing water levels in three pipes of a borehole are similar in value and also recovery rate (after a stress period), they would be tagged as connected regardless of the depth of their openings.

Table A2.2 compares the results of using three different methods to determine connectivity. It is evident that each of these methods could potentially produce false results based on their limitations and fundamental assumptions. These inherent issues were discussed earlier for the Automated method (using Python Scripts), and are inevitable for the depth dependent method. The method chosen for verification (visual comparison of the hydrographs) is probably the most accurate of all, but is impractical to apply to hundreds of hydrographs. The automated method could be used as a rapid appraisal for a large number of sites, however it is recommended that hydrographs for key sites be checked visually. However, if the aquifer has not been under stress for very long periods this method can provide a false indication of high level of connectivity.

Table A2.2
Verification of Connectivity Method for Defining Monitoring Units, Zone 3

Bore Site	Automated Designation	Verified Designation	Traditional Designation-depth dependant (30 m)	Comments
GW036166	P1-Upper P2-Lower P3-Lower	Agree	P1-Lower P2-Lower P3-Lower	Salinity plot suggests a probable leaking problem for pipe 2.
GW036190	P1-Upper P2-Upper P3-Upper	P1-Agree P2-Lower P3-Lower	P1-Upper P2- Lower P3- Lower	It seems the aquifer was not stressed in 1986. The head recovery difference is quite distinguished during the later years on the hydrograph.
GW036200	P1-Upper P2-Upper P3-Upper	P1-Agree P2-Agree P3-Lower	P1-Upper P2- Lower P3- Lower	While the salinity plot shows positive correlation among all the pipes, the hydrograph suggests poor connectivity between pipe 3 and the other two pipes.
GW036151	P1-Upper P2-Lower	Agree	P1-Lower P2-Lower	Hydrograph and salinity plot both are good indicators of poor connectivity between pipe 1 and 2.

The monitoring units assigned to each of the WRL target bores, using the Automated connectivity method is given in Table A2.3.

Table A2.3
Monitoring Units Assigned to WRL Target Bores

Bore No	Pipe No	Average Screen Depth (m)	Monitoring Unit	GWMA	GWMA Zone
GW025012	1	41.15	Upper	(001) Lower Namoi Alluvial	
GW025012	2	76.25	Upper	(001) Lower Namoi Alluvial	
GW025146	1	0	Upper	(001) Lower Namoi Alluvial	
GW025146	2	42.2	Upper	(001) Lower Namoi Alluvial	
GW025146	3	58.75	Upper	(001) Lower Namoi Alluvial	
GW025299	1	69.2	Upper	(001) Lower Namoi Alluvial	
GW025299	2	77.1	Upper	(001) Lower Namoi Alluvial	
GW025321	1	17	Upper	(001) Lower Namoi Alluvial	

Bore No	Pipe No	Average Screen Depth (m)	Monitoring Unit	GWMA	GWMA Zone
GW025321	2	30.05	Upper	(001) Lower Namoi Alluvial	
GW025321	3	34.7	Upper	(001) Lower Namoi Alluvial	
GW025328	1	19.05	Upper	(001) Lower Namoi Alluvial	
GW025328	2	37.05	Lower	(001) Lower Namoi Alluvial	
GW025328	3	64	Lower	(001) Lower Namoi Alluvial	
GW025328	4	82.3	Lower	(001) Lower Namoi Alluvial	
GW025331	1	19.95	Upper	(001) Lower Namoi Alluvial	
GW025331	2	35	Upper	(001) Lower Namoi Alluvial	
GW025331	3	59.35	Lower	(001) Lower Namoi Alluvial	
GW025331	4	70.9	Lower	(001) Lower Namoi Alluvial	
GW030000	1	16.05	Upper	(004) Upper Namoi Alluvium	Zone 3
GW030052	1	20.55	Upper	(004) Upper Namoi Alluvium	Zone 4
GW030052	2	26.65	Upper	(004) Upper Namoi Alluvium	Zone 4
GW030059	1	53.35	Lower	(004) Upper Namoi Alluvium	Zone 6
GW030061	1	53.35	Lower	(004) Upper Namoi Alluvium	Zone 6
GW030063	1	25.9	Upper	(004) Upper Namoi Alluvium	Zone 8
GW030063	2	51.8	Upper	(004) Upper Namoi Alluvium	Zone 8
GW030136	1	8.9	Upper	(005) Peel Valley Alluvium	
GW030140	1	8.55	Upper	(005) Peel Valley Alluvium	
GW030168	1	7.05	Upper	(005) Peel Valley Alluvium	
GW030168	2	19.05	Upper	(005) Peel Valley Alluvium	
GW030184	1	19.55	Upper	(004) Upper Namoi Alluvium	Zone 8
GW030184	2	34.3	Upper	(004) Upper Namoi Alluvium	Zone 8
GW030231	1	15.25	Upper	(004) Upper Namoi Alluvium	Zone 5
GW030231	2	26.65	Upper	(004) Upper Namoi Alluvium	Zone 5
GW030242	1	13	Upper	(001) Lower Namoi Alluvial	
GW030242	2	22.8	Upper	(001) Lower Namoi Alluvial	
GW030242	3	65.55	Lower	(001) Lower Namoi Alluvial	
GW030242	4	79.25	Deeper	(001) Lower Namoi Alluvial	
GW030259	1	29.7	Upper	(001) Lower Namoi Alluvial	
GW030259	2	60.2	Upper	(001) Lower Namoi Alluvial	
GW030306	1	22.85	Upper	(004) Upper Namoi Alluvium	Zone 4
GW030306	2	53.35	Lower	(004) Upper Namoi Alluvium	Zone 4
GW030306	3	83.05	Lower	(004) Upper Namoi Alluvium	Zone 4
GW030329	1	14.05	Upper	(001) Lower Namoi Alluvial	
GW030329	2	28.35	Upper	(001) Lower Namoi Alluvial	
GW030329	3	56.05	Upper	(001) Lower Namoi Alluvial	
GW030344	1	25.15	Upper	(004) Upper Namoi Alluvium	Zone 4
GW030344	2	71.35	Lower	(004) Upper Namoi Alluvium	Zone 4
GW030344	3	115.8	Deeper	(004) Upper Namoi Alluvium	Zone 4
GW030430	1	18.25	Upper	(004) Upper Namoi Alluvium	Zone 3
GW030430	2	38.05	Upper	(004) Upper Namoi Alluvium	Zone 3
GW030430	3	54.8	Upper	(004) Upper Namoi Alluvium	Zone 3
GW030430	4	75.85	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036020	1	42.65	Upper	(001) Lower Namoi Alluvial	
GW036020	2	59.35	Upper	(001) Lower Namoi Alluvial	
GW036022	1	21.3	Upper	(001) Lower Namoi Alluvial	
GW036022	2	37.45	Upper	(001) Lower Namoi Alluvial	
GW036022	3	50.25	Upper	(001) Lower Namoi Alluvial	
GW036094	1	22	Upper	(004) Upper Namoi Alluvium	Zone 5
GW036094	2	72.4	Upper	(004) Upper Namoi Alluvium	Zone 5

Bore No	Pipe No	Average Screen Depth (m)	Monitoring Unit	GWMA	GWMA Zone
GW036094	3	99.8	Upper	(004) Upper Namoi Alluvium	Zone 5
GW036096	1	22.8	Upper	(004) Upper Namoi Alluvium	Zone 5
GW036096	2	41.1	Lower	(004) Upper Namoi Alluvium	Zone 5
GW036140	1	31.95	Upper	(001) Lower Namoi Alluvial	
GW036140	2	56.35	Lower	(001) Lower Namoi Alluvial	
GW036151	1	41.15	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036151	2	87.05	Lower	(004) Upper Namoi Alluvium	Zone 3
GW036166	1	47.2	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036166	2	78.9	Lower	(004) Upper Namoi Alluvium	Zone 3
GW036166	3	97.2	Lower	(004) Upper Namoi Alluvium	Zone 3
GW036190	1	32	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036190	2	53.35	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036190	3	83.8	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036200	1	29.45	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036200	2	44.2	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036200	3	86.85	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036202	1	50.3	Lower	(004) Upper Namoi Alluvium	Zone 3
GW036210	1	18.15	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036210	2	41.45	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036210	3	75.6	Upper	(004) Upper Namoi Alluvium	Zone 3
GW036238	1	21.35	Upper	(004) Upper Namoi Alluvium	Zone 4
GW036238	2	60.95	Upper	(004) Upper Namoi Alluvium	Zone 4
GW036238	3	105.15	Upper	(004) Upper Namoi Alluvium	Zone 4
GW036238	4	124.95	Upper	(004) Upper Namoi Alluvium	Zone 4
GW036314	1	29.5	Upper	(001) Lower Namoi Alluvial	
GW036314	2	52.5	Upper	(001) Lower Namoi Alluvial	
GW036314	3	62	Upper	(001) Lower Namoi Alluvial	
GW036415	1	29.5	Upper	(004) Upper Namoi Alluvium	Zone 12
GW036415	2	45.25	Upper	(004) Upper Namoi Alluvium	Zone 12
GW036415	3	75.7	Upper	(004) Upper Namoi Alluvium	Zone 12
GW036515	1	21.5	Upper	(004) Upper Namoi Alluvium	Zone 2
GW036515	2	64	Lower	(004) Upper Namoi Alluvium	Zone 2
GW036515	3	109	Lower	(004) Upper Namoi Alluvium	Zone 2
GW036541	1	34.5	Upper	(001) Lower Namoi Alluvial	
GW036541	2	58.8	Upper	(001) Lower Namoi Alluvial	
GW036541	3	92.6	Upper	(001) Lower Namoi Alluvial	
GW036566	1	22.5	Upper	(004) Upper Namoi Alluvium	Zone 9
GW036600	1	14	Upper	(004) Upper Namoi Alluvium	Zone 2
GW036600	2	102.5	Lower	(004) Upper Namoi Alluvium	Zone 2
GW036600	3	124.5	Lower	(004) Upper Namoi Alluvium	Zone 2
GW036602	1	17	Upper	(004) Upper Namoi Alluvium	Zone 2
GW036602	2	57.5	Upper	(004) Upper Namoi Alluvium	Zone 2
GW036602	3	88.25	Upper	(004) Upper Namoi Alluvium	Zone 2
GW036654	1	13	Upper	(004) Upper Namoi Alluvium	Zone 9
GW036654	2	34.5	Upper	(004) Upper Namoi Alluvium	Zone 9
GW040822	1	16	Upper	(004) Upper Namoi Alluvium	Zone 6
GW040822	2	29	Upper	(004) Upper Namoi Alluvium	Zone 6
GW040822	3	83	Lower	(004) Upper Namoi Alluvium	Zone 6
GW040822	4	105	Lower	(004) Upper Namoi Alluvium	Zone 6

APPENDIX A3
GROUNDWATER SAMPLING IN JULY INFORMATION PACK

Cotton Catchment Communities CRC

Namoi CMA

June 2009

Dear Namoi Groundwater User,

NAMOI GROUNDWATER SAMPLING MONTH - JULY 2009

This July we are encouraging groundwater users (irrigators and stock & domestic) to collect a water sample from their bore for a FREE partial analysis*.

Sampling bottles can be collected from Namoi Water, NSW Farmers, the Cotton CRC and the Namoi CMA. Monitoring and understanding the status of groundwater levels and groundwater salinity is central to managing this valuable resource and is being helped by this project commissioned by the Cotton CRC and Namoi CMA.

Groundwater level and salinity is being monitored this January, March and July by the University of New South Wales' Water Research Laboratory (led by Dr Wendy Timms). By combining this information with monitoring by the Namoi CMA, the Department of Water and Energy (DWE) and other groundwater projects, Wendy and her team are drawing a picture of how groundwater condition varies over time and across the Namoi.

The project also seeks to understand how groundwater users may get involved in on-going groundwater monitoring and management. Ingrid Roth and her team from GHD Hassall will contact many groundwater users to gather their ideas on this. We encourage you to discuss your thoughts with them and assure you that your views will be treated confidentially.

Samples provided by growers will add value to the data review. The project will lead to establishing a framework for benchmarking groundwater quantity and quality.

Yours sincerely,

Paula Jones	Bronwyn Witts	John Clements
Cotton CRC	Namoi CMA	Namoi Water

If you have any questions, please contact ourselves or the project team:

UNSW Water Research Lab	**GHD Hassall**
Wendy Timms & Duncan Rayner	Ingrid Roth
02 9949 4488	02 6792 5330
d.rayner@unsw.edu.au	(not available 19 May – 1 July)

* The first 200 samples received will be analysed for free, any further samples may need to be charged at a cost of $100/sample.

Namoi Groundwater Sampling In July

A program for Namoi Valley Groundwater users to get involved in testing their bore water quality

Why test groundwater quality in the Namoi Catchment?
Groundwater quality has been found to be a significant issue in some parts of the Namoi Catchment. Operating a groundwater bore without monitoring groundwater level and groundwater quality is "like running a car without a fuel gauge or a dip stick".

What water quality parameters are being tested?
Salinity (electrical conductivity, EC), pH, chloride, sodium, magnesium, calcium, potassium, sulphate and bicarbonate alkalinity. These results will be used to calculate indicators of importance to irrigation usage (total dissolved salts, sodium adsorption ratio and hardness).

Who will take the samples?
Growers and landholders that use groundwater on their property for stock or irrigation purposes. Any growers and landholders in the Namoi catchment can participate in the sampling.

How do I get involved?
Pick up a groundwater sample bottle pack from Namoi Water, NSW Farmers, Cotton CRC offices or Namoi CMA offices (Tamworth, Gunnedah, Narrabri, Walgett) from late June.

This pack will have further instructions about sampling and information that needs to be recorded. If you have access to a water quality meter, measure EC and temperature should be measured immediately when the groundwater flows from the bore. Record this information on the form.

Completed samples can be mailed to UNSW WRL using the mailing pack supplied.

Why collect samples in July?
Groundwater systems in the Namoi are generally most stable in July, thus giving the most accurate readings. This will also coincide with a round of sampling being undertaken by the research team.

Can I use any sample bottle?
No. For quality assurance purposes, registered laboratories do not accept recycled bottles.

Why pump before sampling?
Pumping for at least 15 minutes prior to sampling is essential to purge stagnant water from the bore casing.

Where can I get a water quality meter?
The Namoi CMA has a few EC meters for loan (contact George Truman on 6742-9516).
A basic meter can be purchased for about $150. Further information on where and what to purchase is available on the "DIY Groundwater Monitoring" factsheet on the Cotton CRC website.

How much will it cost?
FREE analysis is being offered for the first 200 samples received provided that these are:

- collected between 1st and 30th July, 2009
- accompanied by a completed sample information form
- one sample per property (preferably from the most frequently used bore)

The Cotton CRC and Namoi CMA are funding the once-off cost of about $150 per sample. If you would like more than one sample to be analysed from your property or if your sample is not amongst the first 200 received then these can be analysed at a cost of $100.

What happens to the testing results?
Sample results will be posted to participants in September, with a 2 page report providing a comment on the suitability of groundwater for irrigation purposes.

Results will be treated anonymously. The data will be grouped and mapped for each aquifer and reported in aggregated form. These maps will be provided to participants and will also available via the Cotton CRC and Namoi CMA websites.

Where do I find out about more comprehensive water quality testing?
This project will be testing for major ions. It will not be testing for microbiological, nutrients, or other trace constituents. Comprehensive tests are recommended for bores used for other purposes such as drinking water, if there is a risk of nearby contaminants, or if there is potential for mining impacts. Suggested contacts: Tamworth Environmental Laboratory ph. 6767 5119, DPI Wollongbar Farm Water Testing ph. 66261103 or Australian Lab Services ph. 8784 8555

Further Information:
http://www.wrl.unsw.edu.au/site/projects

Duncan Rayner
d.rayner@unsw.edu.au, 02 9949 4488

This project is funded by the Cotton CRC and Namoi CMA

Namoi Groundwater in July - Sampling Form

Collection Notes:

- Collect the water sample from a freely flowing bore (ie, at pump outlet or spill point)
- Pump must have been running for at least 15 minutes, prior to sampling
- Rinse the collection container with at least 3 volume of sample water before collecting a sample for measurement.
- Follow manufacturer calibration procedure for the conductivity or pH probe before each measurement.
- Label the sample bottle with the Bore Work No. or your name, sample date and time.

Date	Your name
Property Name	Sampling date
Address	Email

Groundwater Zone		Slotted Interval – Top	(metres)
Date Borehole Installed		Slotted Interval - Bottom	(metres)
Location		How long was the pump running before sampling?	(minutes)
Bore Work No. (or License Number)		Bore reference point (if known):	Top of Casing ______ (m) OR Ground Level ______ (m)
Borehole Total Depth	(m)	Depth to groundwater	(m from reference point)

Location Surveyed   Unknown _____
Known _____   Reading taken from GPS......Topo map... Other.........
Easting _____________   Northing __________

Do you have a meter for measuring water quality: **pH?** Yes / No   **EC?** Yes / No

If yes: How frequently do you monitor the water quality?

☐ Weekly   ☐ Monthly   ☐ 3 monthly   ☐ Occasionally   ☐ Other...............

How often do you calibrate the meter?

If possible, please take measurements of the water at the time of sampling and record these below
(NB most EC meters can also measure temperature)

Temperature of Water	(^{0}C)	pH of Water
Electrical Conductivity (EC) of Water	(dS/m)	

In your view, how important is it for the groundwater condition to be monitored regularly?

- ☐ Very important
- ☐ Somewhat important
- ☐ Not important
- ☐ Don't know

Comment:

Do you see value in landholders contributing their monitoring data to a coordinated groundwater monitoring program?

Yes / No

If yes, who do you think should coordinate this?

- ☐ DWE
- ☐ Namoi CMA
- ☐ Cotton CRC
- ☐ Namoi Water
- ☐ NSW Farmers
- ☐ Cotton Australia
- ☐ Other..............

How do you think information from groundwater monitoring should be communicated to users?

- ☐ Data on website
- ☐ Research reports that review changes in groundwater
- ☐ Newsletters
- ☐ Workshops
- ☐ Groundwater user meetings
- ☐ Other...........................

Would you be interested in participating in on-going groundwater monitoring activity? Yes / No

If yes, how often would you be willing to monitor your groundwater?

- ☐ Monthly
- ☐ Quarterly
- ☐ Annually
- ☐ As often as required

How frequently should this information be made available?

- ☐ Annually
- ☐ When any critical changes are detected
- ☐ Other ....

Would you be willing to share your data through a coordinated program? Yes / No / Maybe

If maybe, what would enable you to do it?

If no, why?

Do you feel you can access information about groundwater condition in the Namoi?

- ☐ Yes - Readily
- ☐ Yes - but not easily
- ☐ No
- ☐ Have not tried to

What would assist you to participate in groundwater monitoring and share your data?
(Please list at least 2 ideas)

Please make any other comments about your thoughts about Namoi groundwater condition and monitoring

Groundwater sample testing permission

I ____________________________________ (name) provide this groundwater sample collected from a bore located on my property for a major ion analysis. I understand that the first sample per property will be analysed free of charge, provided this is amongst the first 200 samples received.*

If my sample is not amongst the first 200 received I would like the WRL to:

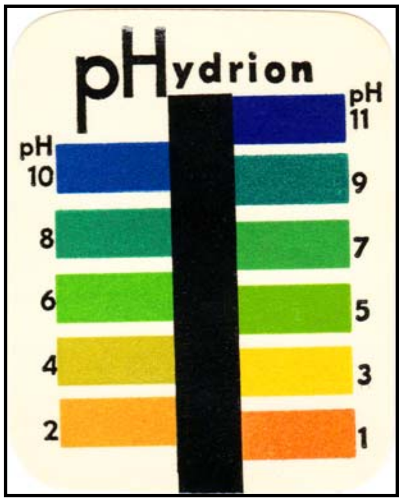
- ☐ Complete the analysis and invoice me for $100
- ☐ Discard my sample without analysis.

I understand that my data will be treated anonymously and will be used in an aggregated form for reporting and analysis by the Cotton CRC, Namoi CMA and researchers at the University of New South Wales Water Research Laboratory.

Signed ___________________________________ Date _____________________

* Additional samples can be analysed at cost, please complete a separate form for each sample and include a cheque made out to "University of New South Wales" for $100 per additional sample and send with the sample to the UNSW Water Research Laboratory, 110 King St., Manly Vale, NSW, 2093.

Water Research Laboratory pH Test Instructions

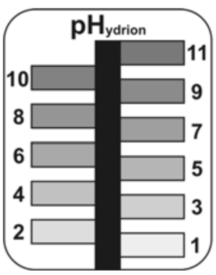


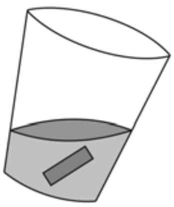
1. Prepare a clear glass

2. Pour 30 – 50 mL (or 1 – 2 cm) of the water sample in the glass

3. Place the pH strip in the sample water and shake gently in a circular motion

4. Wait for a full minute





5. Hold the glass against a dark background, and compare the colour of the pH strip as seen through the sample water with the colour chart shown on this page

6. Record your reading on the appropriate form

Tips:

- *Do not wait any longer than 2 minutes to compare your pH reading, as the colour of your pH strip will change over time.*
- *Make sure you rinse the testing glass well with the same water as your sample, before beginning your pH test to allow greater accuracy of your result.*
- *Repeat the experiment if you are not sure about the result – you have been provide with 2 pH strips to allow this.*

UNSW THE UNIVERSITY OF NEW SOUTH WALES

Water Research Laboratory
King Street, Manly Vale NSW 2093 Australia
Tel: +61 (2) 9949 4488 Fax: +61 (2) 9949 4188
Consulting, Research and Training Services for Industry and Government since 1959

Web: www.wrl.unsw.edu.au
Quality System Certified to AS/NZS ISO 9001:2000

APPENDIX A4
GROUNDWATER SAMPLING IN JULY EXAMPLE RESULTS REPORT

	Electrical conductivity	TDS	Sodium	Calcium	Potassium	Magnesium	Chloride	Sulphate	Bicarbonate	Carbonate	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Sodium Absorption Ratio	Hardness as CaCO3	Anions Total	Cations Total	Ionic Balance
	uS/cm	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**µg/L**	**mg/L**	**units**	**mg/L**	**meq/L**	**meq/L**	**%**
EQL	1		1	1	1	1	0.2	0.2	1	1	1000	1			0.01	0.01	0.01
ANZECC2000			**600[#9]**				**1000[#7]**						**102[#6]**	**350[#15]**			
ANZECC-Barley	*8000[#5]*																
ANZECC-Beef Cattle		10000[#14]															
ANZECC-Cotton	7700[#4]																
ANZECC-Dairy Cattle		7000[#13]															
ANZECC-Irrigation-General							750[#8]										
ANZECC-Irrigation-Specified			460[#18]				700[#18]										
ANZECC-Pigs		8000[#12]															
ANZECC-Poultry		4000[#11]															
ANZECC-Sheep		13000[#10]															
ANZECC-Stock						2000[#20]		1000[#19]									
ANZECC-Stock-Risk								2000[#17]									
ANZECC-Sunflower	5500[#2]																
ANZECC-Wheat	6000[#1]																
Australian Drinking Water		500[#3]	180[#3]				250[#3]	250[#3]						200[#3]			
Early Season Cotton	1500[#16]																

Field_ID	**Sampled_Date-Time**	Electrical conductivity	TDS	Sodium	Calcium	Potassium	Magnesium	Chloride	Sulphate	Bicarbonate	Carbonate	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Sodium Absorption Ratio	Hardness as CaCO3	Anions Total	Cations Total	Ionic Balance
G exp	29/07/2009	960	670.9	50	64	3	51	69.7	19.2	414	<1	<1000	414	1.1	**369.6**	10.6	9.65	4.86

Comments

#1 Unsuitable for Wheat irrigation.
#2 Unsuitable for Sunflower irrigation.
#3 Unsuitable for drinking.
#4 Unsuitable for Cotton irrigation.
#5 Unsuitable for Barley irrigation.
#6 Stunted growth for Cotton and Sunflower
#7 Risk to cotton growth.
#8 Risk of increased Cadmium intake by crops.
#9 Non-satisfactory for stock.
#10 Loss of production and a decline in sheep condition and health.
#11 Loss of production and a decline in poultry condition and health.
#12 Loss of production and a decline in pigs condition and health.
#13 Loss of production and a decline in dairy cattle and horses condition and health.
#14 Loss of production and a decline in beef cattle condition and health.
#15 Increased fouling potential of water.
#16 If used on early season cotton, the final yields could be diminished.
#17 Chronic acute health problems in stock.
#18 Causing foliar injury in Cotton and Sunflower.
#19 Adverse effects on stock.
#20 Adverse effects on cattle.

Groundwater Sampling in July – Explanatory Notes for Reports

Electrical conductivity (EC): a measure of water's salinity. Seawater has an approximate EC value of 55000 µS/cm, while Rain water (inland) was measured to have an average value of 10 µS/cm. Soil and water salinity criteria base on plant salt tolerance as defined by ANZECC 2000 is as follows;

Sensitivity Group	EC range
Sensitive crops	950 µS/cm
Moderately Sensitive crops	950-1900 µS/cm
Moderately tolerant crops	1900-4500 µS/cm
Tolerant crops	4500-7700 µS/cm
Very tolerant crops	7700-12200 µS/cm
Generally too saline	>12200 µS/cm

TDS: or total dissolved solids, is the combined content of all inorganic and organic substances in a liquid. TDS is often the sum of Calcium, Sodium, Potassium, Magnesium, Chloride, Sulfate, and Bicarbonate. A general guideline for TDS values for drinking water (ANZECC 2000) is as follows;

TDS value	Water Quality
<80 mg/l	Excellent quality
80-500 mg/l	Good quality
500-800 mg/l	Fair quality
800-1000 mg/l	Poor quality
>1000 mg/l	Unacceptable

pH: a measure of acidity or alkalinity. Neutral water has ph value of 7.0. An acceptable pH value for drinking water according to the Australian Drinking Water Guidelines is between 6.5 and 8.5 pH units

Hardness as $CaCO_3$: Water hardness refers to the presence in water of calcium and magnesium, the origin of which is related to geological characteristics at the water's source.

Water Hardness as $CaCO_3$ (mg/l)- ANZECC 2000	< 200 to reduce scale
	> 350 increased fouling potential

Sodium Adsorption Ratio (SAR): analysis of the Sodium hazard in the water; i.e. an imbalance in the ratio of Sodium to Calcium. This could lead to problems with soil structure, namely crusting, poor water penetration, and poor drainage particularly with clay soils. A general guideline for SAR values (Hounslow, 1995) is as follows;

SAR range	Description
<10	Low
10-18	Medium
18-26	High
>26	Very high

EQL: Or Estimated Quantitation Limit is the lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions.

The standard analysis methods used by Australian Laboratory Services (ALS) are provided in the following table.

Chemical Name	Method Name	Method Type
Electrical conductivity	Conductivity by PC titrator	EA010P
TDS (Total Dissolved Solids)	ESDAT combined compound	ESDAT
Sodium, Calcium, Potassium, Magnesium	Dissolved major cations	ED093F
Chloride, Sulphate	Anions	ED009
Bicarbonate, Carbonate, Alkalinity(total and Hydroxide) as $CaCO_3$	Alkalinity by PC titrator	ED037P
Total Anions, Total Cations, Ionic balance	Ionic Balance	EN055

APPENDIX A5
WRL TARGET MONITORING BORES

WORK_NO	Pipe	GMA	Zone	Monitoring Unit	Purpose or issue				Comments
					Near stream	Irrigation	Groundwater level change	Water quality	
GW025012	1	(001) Lower Namoi Alluvial		Upper			Y		**Pilliga input no pumping influence but show slow decline**
	2			Upper					
GW025146	3	(001) Lower Namoi Alluvial		Upper			Y		**Between Palaeochannels (no hydrograph plot yet)**
GW025299	1	(001) Lower Namoi Alluvial		Upper		Y	Y		**Northern Palaeochannel major region of decline (pipe 2)**
	2			Upper					
GW025321	2	(001) Lower Namoi Alluvial		Upper			Y		**Some decline very little pumping influence**
GW025328	1	(001) Lower Namoi Alluvial		Upper	Y				**Core recharge zone measure pipes 1 and 4 (pipe 2 bad data)**
	4			Lower					
GW025331	2	(001) Lower Namoi Alluvial		Upper	Y				**Core recharge zone (no hydrograph plot yet)**
	3			Lower					
	4			Lower					
GW030000	1	(004) Upper Namoi Alluvium	3	Upper	Y	Y			**Mooki River at Breeza, assess impact of pumping on GW quality**
GW030052	1	(004) Upper Namoi Alluvium	4	Upper			Y		**Rising trend in GW level**
	2			Upper					
GW030059	1	(004) Upper Namoi Alluvium	6	Lower			Y		**Seasonal fluctuating water level**
GW030061	1	(004) Upper Namoi Alluvium	6	Lower					**Yarramanbah CSIRO site**

WORK_NO	Pipe	GMA	Zone	Monitoring Unit	Purpose or issue				Comments
					Near stream	Irrigation	Groundwater level change	Water quality	
GW030063	1	(004) Upper Namoi Alluvium	8	Upper		Y	Y		**Irrigation drawdown, (replace GW030184?)**
	2			Upper					
	3								
GW030136	1	(005) Peel Valley Alluvium		Upper	Y				**Peel alluvium near Tamworth, DWE monitoring to 2008**
GW030140	1	(005) Peel Valley Alluvium		Upper	Y				**Peel alluvium**
GW030168	1	(005) Peel Valley Alluvium		Upper	Y				**Peel alluvium (or GW030167)**
	2			Upper					
GW030184	1	(004) Upper Namoi Alluvium	8	Upper			Y		**Declining trend induced by pumping**
	2			Upper					
GW030231	1	(004) Upper Namoi Alluvium	5	Upper	Y				**Maules Creek CWI nominated (pipe 1 & 2)**
	2			Upper					
GW030242	1	(001) Lower Namoi Alluvial		Upper			Y		**Slow decline all pipes inflow region**
	2			Upper					
GW030259	1	(001) Lower Namoi Alluvial		Upper			Y		**Stable flat hydrograph in flow region**
	2			Upper					
GW030306	1	(004) Upper Namoi Alluvium	4	Upper	Y	Y			**Assess impact of pumping on GW quality**
	2			Lower					
GW030329	1	(001) Lower Namoi Alluvial		Upper			Y		**Interbasin inflow (no hydrograph plot yet)**
	3			Upper					

WORK_NO	Pipe	GMA	Zone	Monitoring Unit	Purpose or issue				Comments
					Near stream	Irrigation	Groundwater level change	Water quality	
GW030344	1	(004) Upper Namoi Alluvium	4	Upper		Y			**Assess impact of pumping on GW quality**
	2			Lower					
	3			Deeper					
GW030430	2	(004) Upper Namoi Alluvium	3	Upper					**A bench mark (data available since 1974)**
	4			Upper					
GW036020	1	(001) Lower Namoi Alluvial		Upper				Y	**Saline top soil region**
	2			Upper					
GW036022	2	(001) Lower Namoi Alluvial		Upper	Y				**Core recharge one of the best for showing the connection to the river**
	3			Upper					
GW036094	1	(004) Upper Namoi Alluvium	5	Upper					**Maules Creek CWI nominated (pipe 1 & 3)**
	3			Upper					
GW036096	1	(004) Upper Namoi Alluvium	5	Upper	Y				**Maules Creek CWI nominated (pipe 1 & 2)**
	2			Lower					
GW036130	1	(004) Upper Namoi Alluvium		(blank)					
GW036140	1	(001) Lower Namoi Alluvial		Upper			Y		**Southern Palaeochannel modest decline**
	2			Lower					
GW036151	1	(004) Upper Namoi Alluvium	3	Upper					
	2			Lower					

WORK_NO	Pipe	GMA	Zone	Monitoring Unit	Purpose or issue				Comments
					Near stream	Irrigation	Groundwater level change	Water quality	
GW036166	1	(004) Upper Namoi Alluvium	3	Upper				Y	**Increasing salinity (Lavitt97), replaces GW036200, GW036097**
	2			Lower					
	3			Lower					
GW036190	1	(004) Upper Namoi Alluvium	3	Upper					
GW036200	2	(004) Upper Namoi Alluvium	3	Upper					
	3			Upper					
GW036202	1	(004) Upper Namoi Alluvium	3	Lower					
GW036210	1	(004) Upper Namoi Alluvium	3	Upper		Y			**Assess impact of pumping on GW quality**
	3			Upper					
GW036238	1	(004) Upper Namoi Alluvium	5	Upper		Y			**Assess impact of pumping on GW quality, replaces GW036239**
	2			Upper					
	3			Upper					
	4			Upper					
GW036314	1	(001) Lower Namoi Alluvial		Upper				Y	**Far west very saline bore water (pipe 3)**
	2			Upper					
	3			Upper					
GW036415	1	(004) Upper Namoi Alluvium	12	Upper	Y	Y			**Assess impact of pumping on GW quality**
	3			Upper					

WORK_NO	Pipe	GMA	Zone	Monitoring Unit	Purpose or issue				Comments
					Near stream	Irrigation	Groundwater level change	Water quality	
GW036515	1	(004) Upper Namoi Alluvium	2	Upper			Y		**Declining trend induced by pumping**
	3			Lower					
GW036541	1	(001) Lower Namoi Alluvial		Upper					**Cryon NAP site**
	2			Upper					
	3			Upper					
GW036566	1	(004) Upper Namoi Alluvium	9	Upper					
GW036600	2	(004) Upper Namoi Alluvium	2	Lower			Y		**Rising trend in GW level**
	3			Lower					
GW036602	1	(004) Upper Namoi Alluvium	2	Upper			Y		**Declining trend induced by pumping**
	2			Upper					
	3			Upper					
GW036654	1	(004) Upper Namoi Alluvium	9	Upper		Y			**Assess impact of pumping on GW quality**
	2			Upper					
GW040822	1	(004) Upper Namoi Alluvium	6	Upper					**Yarramanbah CSIRO site (next to GW030061)**
	4			Lower					
GW036515	1	(004) Upper Namoi Alluvium	2	Upper			Y		**Declining trend induced by pumping**
	3			Lower					
GW036541	1	(001) Lower Namoi Alluvial		Upper					**Cryon NAP site**

Sample	Location	Adjacent Bore (Bore-Pipe)	Latitude	Longtitude
SURFACE # 1	Namoi River	GW025331-2	-30.2031	149.5444
SURFACE # 2	Namoi River	GW036096-1	-30.5506	149.9978
SURFACE # 3	Cox Creek	GW036654-1	-31.4565	149.9358
SURFACE # 4	Tamworth	GW030136-1	-31.0821	150.9122
SURFACE # 5	Peel River	GW030168-1	-31.1808	151.0667
SURFACE # 6	Mooki River/Breeza Plain	GW030000-1	-31.2574	150.4732
SURFACE # 7	Mooki River	GW030430-2	-31.1616	150.4273

Work No	Pipe	Date	Reason for failure
GW025146	1	Jan-09	DRY, CASING SUBSIDENCE
GW036600	1	Jan-09	DRY
GW030306	3	Jan-09	COLLAPSED AT 38 m
GW030030		Jan-09	COLLAPSED
GW030063		Jan-09	LOCKED BY MINE
GW036022	1	Jan-09	PIPE 1 DRY
GW036022	3	Jan-09	PIPE 3 COLLAPSED AT 42.8 m ABOVE SCREE
GW025146	1	Mar-09	DRY
GW025146	2	Mar-09	SWL at bottom of screen
GW025321	1	Mar-09	DRY
GW025321	3	Mar-09	Broken pipe
GW030259	1	Mar-09	Blocked at 34m
GW036200	1	Jul-09	Blocked at 27.5 m
GW030306	3	Jul-09	Blocked at 37 m
GW036022	1	Jul-09	Dry
GW036022	3	Jul-09	Blocked at 40.5 m
GW025146	2	Jul-09	Dry
GW025146	3	Jul-09	SWL below the screen
GW025321	3	Jul-09	Bent Pipe

APPENDIX A6
MONITORING BORE SAMPLING PROCEDURES

1. Sampling Method

1.1 Preparation for Sampling

Pre-treated containers appropriate to the parameters being measured should be obtained from the laboratory that will analyse the samples. Sample collectors should use the attached checklist to ensure that all necessary equipment is taken into the field.

1.2 In the Field

Due to the low flow in the bores, sampling may need to be conducted over two days. On the first day all of the bores will be purged, whilst on the second water that has flowed into the hole may be sampled.

For each borehole

1. Calibrate water quality meters at the beginning of each day.
2. Measure the SWL within the borehole to the top of the steel borehole protector.
3. Lower the pump into the borehole to a depth above the well screen to ensure the screen is not dewatered.
4. Commence pumping of the borehole, noting the volume of water pumped by filling a bucket of known dimensions
5. Begin taking field measurements using water quality meters for pH, EC, T in a flow cell. When measurements have stabilised within +/-10%, final field measurements should be recorded and samples can be taken. Measurements must be made of these parameters on-site.
6. Fill all pre-prepared bottles to the top without headspace, taking care not to lose any of the preservative from the bottle. LABEL EACH CONTAINER CLEARLY AT TIME OF SAMPLING.
7. Return samples to chilled esky or portable refrigerator.
8. Disinfect pumping equipment before proceeding to the next bore.

1.2.1 Calibration of Meters

Water quality meters must be calibrated to standard solutions according to the manufacturers instructions at the beginning of each sampling day.

1.2.2 Measuring Standing Water Level

Standing water level should be measured in each borehole prior to pumping. Care must be taken to record the reference level from which the measurement has been made eg. Top of the steel borehole protector or PVC casing.

1.2.3 Purging or Micropurging

The well or borehole should be sufficiently pumped prior to sampling to ensure that the water sampled is representative of the aquifer (AS/AZS 5667.1:1998). Either the volume of water pumped should be measured, or a flow rate and amount of time pumping. This can be completed with a bucket of known volume and a stop watch.

Table 1. Volume of water in bore casing

Casing Diameter (mm)	Volume of Water per m of casing (L)
50	2.0
65	3.3
100	7.9
150	17.7
200	31.4
250	49.1
300	70.7

Changes within field parameters should be +/- 10% prior to sampling, or less than +/- 0.2 ^{o}C and at least one borehole volume of water extracted (AS/AZS 5667.11:1998), although it is generally recommended that 3-4 borehole volumes are pumped (Jiwan & Gates, 1992). Submersible pumps are the preferred device for sampling (Jiwan & Gates, 1992), and where not available a bailer should be used.

For large diameter wells where purging may take an excessive amount of time and require disposal of excessive amount of purge water, it may be preferable to use low-flow (or micropurging) sampling techniques. The following conditions should be noted:

- Pumping equipment should be lowered slowly and carefully into the bore down to the middle to the top of the well screen, taking care to reduce mixing of the water column.
- Pumping can commence immediately at flow rates comparable with the likely recovery rate of the well (generally between 100-1000 mL/min).
- The pumping equipment needs to be purged prior to commencing sampling.
- Sampling can only be completed when 3 consecutive measurements within 10 minutes of field parameters (DO, Eh and turbidity) are within +/- 10%.
- As for traditional sampling, flow rates and volume of water purged should be measured.
- Drawdown should be vigorously monitored and excessive drawdown avoided (preferably drawdown should be <0.1 m)

For low-yielding bores that can not be pumped even at low-flow rates (100 mL/min), Varljen (2003) and Sevee *et al* (2000) maintain that it is best to use passive sampling techniques at the well screen, rather than dewater the bore and take samples of the recovered water. This is due to the effects that oxidation may have on the well screen and aquifer formation. This may mean lowering tubing to the well screen, leaving it for a day then taking a sampling with a peristaltic pump or a micropurge pump. If these methods are not available, dewatering the bore and bailing the recovered water may be used as a last resort.

1.2.4 Recording Data

Prior to sampling each borehole, the standing water level in the bore should be measured from the top of the steel casing, together with the time and date of the measurement. Information that needs to be recorded includes:

- Standing water level
- Calibration of meters
- Set depth of pump
- Volume of water pumped
- Method of sampling
- Sample Appearance at time of collection (colour, clarity and odour).
- Preservation techniques
- Field parameters, such as pH, EC, DO.
- Any information which may affect the results of the analysis

Sample collectors should complete a copy of the attached field sheet for each borehole to ensure that all necessary information is recorded.

1.2.5 Sampling

When taking microbiological samples, latex gloves should be worn to prevent contamination of the sample. Care must be taken not to touch the top of the bottle during removal or replacement of the lid and the cap should never be placed on any surface. The cap must be replaced tightly as soon as the container is filled, and the sample must be kept chilled until it reaches the laboratory.

It is best that all samples containers are filled to the top without any headspace, taking care not to overfill the bottles as preservative may be lost. Check all bottlecaps are tightly secured. Each sample must be clearly labelled at the time of sampling with the bore hole ID and the date of sampling.

1.2.6 Preservation and Transport of Samples

Groundwater samples obtained for water quality analysis are to be collected, handled and preserved as per the Standards Association of Australia (1998) '*Water Quality - Sampling Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples'* Australian/New Zealand Standard AS/NZS 5667.1:1998. These guidelines contain specific protocols and procedures suitable for groundwater quality sampling and analysis.

Filled sample containers should be kept cold in an esky with ice-packs. Samples for microbiological analysis should arrive at the laboratory within 24 hours of sampling and must be kept chilled. Packing material should be used to fill the esky prior to courier to the laboratory. Samples should arrive at the laboratory on Thursday afternoon at the latest to ensure that the microbiological analysis can be completed prior to the weekend.

Chain-of-custody documentation as required by the laboratory should be included in the esky with the samples, and should include the ID's of each sample and the analysis required.

1.2.7 Disinfection

Disinfection is not required for this project since micro-biological parameters are not analysed.

1.3 Laboratory Analysis

Groundwater sample analysis is to be undertaken by a laboratory that is NATA-registered for the analysis conducted.

2. Quality Control

Groundwater sampling is to be undertaken by suitably trained personnel, following the procedures laid out in this document. It is recommended that 5% of samples be submitted as blind duplicates, and one blank (distilled water) and one spiked sample should be submitted with every 20 samples (Jiwan & Gates, 1992).

3. References

Jiwan, J. & Gates, G. (1992) "A Practical Guide to Groundwater Sampling" Department of Water Resources, Technical Services Division

Sevee, J.E., White, C.A. & Maher, D.J. (2000). "An Analysis of Low-Flow Ground Water Sampling Methodology". GWMR, Spring 2000, pp 87-93.

Standards Australia & Standards New Zealand (1998) '*Water Quality -Sampling Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples'* Australian/New Zealand Standard AS/NZS 5667.1:1998

Standards Australia & Standards New Zealand (1998) '*Water Quality –Sampling Part 11: Guidance on Sampling of Groundwaters'* Australian/New Zealand Standard AS/NZS 5667.11:1998

Varljen, M. (2003) "Low-Flow Groundwater Sampling" Presentation at ITRC 2003 Fall Meeting.

APPENDIX A7
WRL MONITORING RESULTS – TABLES AND MAPS

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW025012	1	Jan-09	28.07	1188	1334	7.5	1.09	119	25	329	4	6	4	85	27	601	733.22	<1	<1000	601	26.44	27.83	0.09
		Mar-09	28.1	–	1364	7.54	0.92	-40	26.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	28.1	–	1249	7.51	0.86	127	21.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Jan-09	27.37	2013	2728	7.21	0.14	-56	26	610	17	7	10	472	70	678	827.16	<1	<1000	678	83.57	29.03	0.06
		Mar-09	27.41	–	2790	7.2	0.21	-174	25.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	27.44	–	2553	7.17	0.04	-63	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW025146	2	Jan-09	41.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Mar-09	41.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Jan-09	42.89	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Mar-09	42.18	294.6	382	6.61	4.9	242	25.6	50	16	1	9	11	10	162	197.64	<1	<1000	162	76.96	2.48	0.88
		Jul-09	41.47	–	367	6.57	4.86	274	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW025299	1	Mar-09	51.26	1824	2963	7.42	0.66	-229	27.4	471	81	3	61	676	144	318	387.96	<1	<1000	318	453.1	9.62	2.02
		Jul-09	46.5	2863	4190	7.15	1.59	-32	24.1	699	162	4	111	1200	332	291	355.02	<1	<1000	291	861	10.36	1.28
	2	Mar-09	54.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	46.53	2569	3810	7.17	1.63	-106	24.2	630	146	4	99	1060	292	277	337.94	<1	<1000	277	771.7	9.86	1.86
GW025321	1	Jul-09	18.84	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Jan-09	20.12	773.2	931	7.16	5.23	-51	23.1	183	18	1	10	69	14	392	478.24	<1	<1000	392	86.06	8.58	1.73
		Mar-09	20.1	–	1132	7.37	5.44	-133	26.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	19.92	747.1	821	7.28	5.2	146	20	177	19	1	10	66.9	10.8	379	462.38	<1	<1000	379	88.56	8.18	0.8
GW025328	1	Jan-09	17.53	426.4	591	6.1	4.12	126	24.1	54	32	2	21	49	39	188	229.36	<1	<1000	188	166.3	1.82	1.96
		Mar-09	17.64	–	597	6.39	5.2	74	24.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	Jan-09	30.03	745.3	854	7.25	0.35	75	23.7	159	25	3	10	29	2	424	517.28	<1	<1000	424	103.5	6.80	1.4
		Mar-09	28.38	–	852	7.41	0.64	-127	25.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW025331	2	Feb-09	16.6	_	412	6.52	0.07	-107	22.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Mar-09	16.99	_	424	6.38	0.21	-46	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	19.15	287.7	382	6.48	0.13	48	21.2	32	25	2	14	28.9	30.9	127	154.94	<1	<1000	127	120	1.27	1.12
	3	Mar-09	21.31	_	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	21.63	325.5	414	6.45	0.08	-36	20	20	36	2	20	27.4	21.2	163	198.86	<1	<1000	163	172.1	0.66	0.7
	4	Feb-09	23.04	206.4	272	6.04	0.08	-171	22.2	20	17	4	8	6	0	120	146.4	<1	<1000	120	75.34	1.00	_
		Mar-09	22.03	_	522	6.96	0.1	-222	22.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	22.32	435.9	476	7.01	0.04	-119	20.1	98	9	2	5	12.5	1.92	252	307.44	<1	<1000	252	43.03	6.50	1.76
GW030000	1	Feb-09	12.47	689.2	925	7.61	3.74	118	21.4	96	46	2	34	101	32	310	378.2	<1	<1000	310	254.7	2.62	1.86
		Jul-09	13.57	745.6	1047	7.58	0.07	176	20.1	102	48	2	37	123	28.6	332	405.04	<1	<1000	332	272	2.69	3.77
		Apr-09	12.61	_	940	7.38	1.23	182	20.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030052	1	Feb-09	13.87	806.9	960	7.1	1.35	-143	22.3	136	56	1	18	76	38	395	481.9	<1	<1000	395	213.8	4.05	3.19
		Jul-09	13.91	803.9	954	6.99	1.58	-31	21.5	139	59	1	19	80.5	28.4	391	477.02	<1	<1000	391	225.4	4.03	0.39
		Apr-09	13.88	_	1101	7.17	1.5	-48	22.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Feb-09	13.8	706.1	917	7.05	3.51	-36	22.4	131	39	1	16	60	26	355	433.1	<1	<1000	355	163.1	4.46	1.67
		Jul-09	13.91	792.8	931	7	3.42	28	21.9	138	55	1	18	78.4	24.2	392	478.24	<1	<1000	392	211.3	4.13	1.39
		Apr-09	13.89	_	967	7.13	3.92	84	23.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030059	1	Feb-09	7.13	563.1	831	7.2	0.09	-223	20.4	115	17	8	18	99	6	246	300.12	<1	<1000	246	116.5	4.63	1.72
		Apr-09	7.13	_	818	7.33	0.36	-167	23.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030061	1	Feb-09	_	1003	1584	8.14	0.05	-248	21.6	283	11	4	19	275	28	314	383.08	8	<1000	322	105.6	11.98	0.85
		Jul-09	2.05	983.3	1362	8.22	0	-96	20.1	268	10	3	18	279	10	324	395.28	<1	<1000	324	99.02	11.71	2.82
		Apr-09	1.88	_	1532	8.14	0.27	-251	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030063	1	Apr-09	25.07	746.7	1108	7.11	5.41	-39	24.2	52	82	2	50	109	65	317	386.74	<1	<1000	317	410.4	1.12	0.8
	2	Apr-09	25.76	740.5	1076	7.12	4.19	13	23.5	50	71	2	54	110	68	316	385.52	<1	<1000	316	399.4	1.09	2.86

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW030063																							
	3	Apr-09	_	720.1	1030	_	_	_	_	52	78	2	56	115	56	296	361.12	<1	<1000	296	425.1	1.10	2.57
GW030136	1	Feb-09	6.65	457.1	634	66.6	0.07	-94	22.7	29	57	_	24	39	49	212	258.64	<1	<1000	212	241	0.81	1.92
		Jul-09	7.22	457.5	606	6.84	0.06	10	20.1	30	59	_	24	50.6	45.7	203	247.66	<1	<1000	203	246	0.83	1.48
		Apr-09	8.92	_	646	6.96	0.12	-8	21.8	_	_	_	_	_	_	_	_	_	_	_	_	_	_
GW030140	1	Feb-09	5.83	381.2	523	7.02	0.21	-129	21.8	31	38	_	21	20	34	194	236.68	<1	<1000	194	181.2	1.00	1.8
		Jul-09	6.39	_	568	6.98	0.84	-49	19.5	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Apr-09	6.09	_	531	6.97	0.21	-78	21.2	_	_	_	_	_	_	_	_	_	_	_	_	_	_
GW030168	1	Feb-09	4.24	282.8	391	6.25	0.07	91	20.4	19	28	_	18	8	19	156	190.32	<1	<1000	156	143.9	0.69	0.34
		Jul-09	4.29	274.7	363	6.98	0.4	83	19.4	18	26	1	18	9.83	14	154	187.88	<1	<1000	154	138.9	0.66	1.08
		Apr-09	4.42	_	392	7.08	0.12	6	20.3	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	2	Feb-09	4.18	263.3	386	6.66	0.02	-176	20.8	14	28	2	16	9	15	147	179.34	<1	<1000	147	135.7	0.52	0.86
		Jul-09	4.23	293.5	367	6.83	0.16	30	18.8	15	32	1	19	14.9	14	162	197.64	<1	<1000	162	158	0.52	1.63
		Apr-09	4.42	_	390	6.95	0.06	-145	19.8	_	_	_	_	_	_	_	_	_	_	_	_	_	_
GW030184	1	Feb-09	17.68	718.3	1117	6.88	2.09	30	23.8	62	81	2	45	106	38	315	384.3	<1	<1000	315	387.3	1.37	1.92
		Jul-09	16.43	_	953	6.93	1.92	108	21.3	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Apr-09	17.01	_	1086	6.81	2.26	82	22.9	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	2	Feb-09	17.43	760.9	1105	6.81	1.72	37	21.6	62	86	2	48	111	42	336	409.92	<1	<1000	336	412.1	1.33	1.18
		Jul-09	16.19	_	946	6.88	1.61	102	21.5	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Apr-09	16.77	_	1060	6.79	1.95	103	22.7	_	_	_	_	_	_	_	_	_	_	_	_	_	_
GW030231	1	Jan-09	7.34	436.6	565	7	0.1	-10	22.6	64	34	3	12	33	10	230	280.6	<1	<1000	230	134.2	2.40	1.72
		Mar-09	7.5	_	585	6.94	0.1	37	21.1	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Jul-09	7.47	_	534	6.75	0.05	213	19	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	2	Feb-09	_	275.7	_	_	_	_	_	32	23	4	12	26	25	126	153.72	<1	<1000	126	106.8	1.35	1.6

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW030231	2																						
		Jan-09	7.35	388.2	474	6.95	0.58	15	24.2	59	30	2	10	20	22	201	245.22	<1	<1000	201	116	2.38	0.6
		Mar-09	7.53	–	483	6.97	0.38	52	21.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	7.48	–	442	6.78	0.72	193	18.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030238	1	Jul-09	–	490.6	–	–	–	–	–	45	56	–	29	59.2	75.2	185	225.7	<1	<1000	185	259.1	1.22	1.21
		Jan-09	13.83	764.2	616	6.91	–	–	22.9	104	47	6	31	33	4	442	539.24	<1	<1000	442	244.8	2.89	1.39
		Mar-09	13.64	–	623	6.8	5.52	37	21.8	–	–	–	–	–	–	–	–	<1	–	–	–	–	–
		Jul-09	13.52	–	596	6.82	5.07	208	21.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Jan-09	13.95	485.2	878	6.49	3.03	78	24.4	96	18	2	17	51	23	228	278.16	<1	<1000	228	114.9	3.90	0.21
		Mar-09	13.7	–	864	6.61	0.13	8	22.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	13.59	–	864	6.53	0.42	161	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030259	1	Feb-09	8.3	5250	6727	7.4	0.3	-3.7	27	1610	18	16	39	1180	374	1650	2013	<1	<1000	1650	205.4	48.86	0.43
		Jul-09	8.22	–	6160	7.44	0.23	119	23.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Feb-09	4.49	1132	1247	7.83	0.08	-252	25.6	325	5	3	1	49	0	612	746.64	31	<1000	643	16.59	34.71	1.15
		Mar-09	4.55	–	1259	8.01	0.09	-270	23.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	3.34	–	1201	7.77	0.11	-200	23.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030306	1	Feb-09	13.67	411.3	613	6.62	0.05	-184	22.1	37	42	2	22	48	37	183	223.26	<1	<1000	183	195.3	1.15	1.92
		Jul-09	13.74	–	600	6.73	0.04	52	20.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Apr-09	13.78	–	653	6.88	0.13	-133	22.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Feb-09	17.4	391.1	573	6.53	0.1	33	22	29	46	2	23	39	41	173	211.06	<1	<1000	173	209.4	0.87	0.95
		Jul-09	15.91	–	565	6.68	0.45	-13	19.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Apr-09	15.91	–	592	6.86	0.3	116	24.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Jul-09	20.45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030329	1	Jan-09	11.18	1370	1564	7.61	7	24	23.5	403	5	1	2	144	44	632	771.04	<1	<1000	632	20.71	38.52	1.02

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW030329	1																						
		Mar-09	11.12	_	1564	7.45	0.34	-77	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Jan-09	14.11	1052	1115	7.57	0.17	-71	23.2	299	2	2	_	42	16	566	690.52	<1	<1000	566	_	_	1.2
		Mar-09	12	_	1118	8.36	0.1	-217	24.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030344	1	Feb-09	17.82	402.2	589	6.83	6.02	90	21.6	27	48	_	23	48	30	185	225.7	<1	<1000	185	214.4	0.80	1.94
		Jul-09	15.36	_	594	6.8	5.11	60	19.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Apr-09	16.14	_	617	6.93	6.27	60	20.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Jul-09	15.08	_	303	6.72	1.474	-26	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Feb-09	25.42	463.5	564	7.9	0.23	7	21.7	62	31	2	18	10	16	266	324.52	<1	<1000	266	151.4	2.19	1.44
		Jul-09	15.24	_	669	5.79	0.09	-11	20.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Apr-09	16.87	_	603	6.04	0.11	11	22.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW030430	1	Jul-09	19.74	_	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Feb-09	23.85	648.2	885	7.81	1.73	73	223	144	21	1	16	74	25	301	367.22	<1	<1000	301	118.2	5.76	0.25
		Jul-09	20.41	_	877	7.62	1	217	20.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Apr-09	21.29	_	858	7.67	1.9	131	23.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Jul-09	19.75	_	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	Feb-09	23.56	603.2	736	7.49	1.29	85	23.1	121	23	2	13	40	15	319	389.18	<1	<1000	319	110.9	5.00	1.72
		Jul-09	19.58	_	782	7.03	1.52	180	19.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Apr-09	20.54	_	760	7.4	1.44	66	23.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036020	1	Jan-09	30.89	653.1	741	7.04	2.12	118	25	168	4	3	5	28	23	346	422.12	<1	<1000	346	30.56	13.22	1.2
		Mar-09	30.94	_	769	7.01	2.03	167	24.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	30.94	_	710	6.9	1.52	-6	23.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Jan-09	31.46	867.5	1004	6.99	1.1	158	24.5	238	5	4	4	61	26	434	529.48	<1	<1000	434	28.94	19.25	0.39
		Mar-09	31.03	_	817	6.67	1.4	17	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW036020	2																						
		Jul-09	31.04	_	775	6.93	1.06	-202	23.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036022	2	Jan-09	24.35	246.6	328	6.5	2.88	123	24.6	31	20	2	10	13	12	130	158.6	<1	<1000	130	91.05	1.41	0.5
		Jul-09	23.48	_	325	6.21	2.92	186	21.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Mar-09	24.33	_	336	6.39	3.11	57	26.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	24.67	_	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036094	1	Jan-09	14.71	474.9	535	6.62	6.03	109	24.9	69	35	2	18	51	40	213	259.86	<1	<1000	213	161.4	2.36	1.45
		Mar-09	12.16	_	525	6.56	6.34	191	21.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	11.43	_	469	6.55	6.54	181	19.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Jan-09	20.99	596.7	755	695	0.09	-136	23.4	131	26	2	8	51	42	276	336.72	<1	<1000	276	97.79	5.76	0.69
		Mar-09	12.39	_	769	7.19	0.06	-120	23.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	11.44	_	712	6.46	0.16	-176	21.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036096	1	Jan-09	10.38	371.8	652	6.64	0.07	87	22.5	56	33	2	12	38	21	172	209.84	<1	<1000	172	131.7	2.12	1.35
		Mar-09	10.77	_	656	6.58	0.39	46	22.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	10.75	454.3	594	6.58	0.96	-1	21.6	63	35	2	19	50.4	38.5	202	246.44	<1	<1000	202	165.5	2.13	1.17
	2	Jan-09	12.56	461.1	653	6.43	0.16	93	53.2	26	57	2	28	59	39	205	250.1	<1	<1000	205	257.4	0.70	1.9
		Mar-09	11.55	_	669	6.59	0.32	35	23.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	11.3	481.4	610	6.39	0.25	19	21.6	23	59	2	30	63.1	35.9	220	268.4	<1	<1000	209	270.7	0.61	1.78
GW036130	1	Jul-09	_	2074	3740	8.03	0.12	122	19.8	593	33	1	46	866	223	256	312.32	<1	<1000	256	271.6	15.65	4.43
GW036140	1	Mar-09	29.11	_	492499	6.5	6.79	180	27.3	6570	2426	12	1214	2131	610	220231	0	<1	<1000	220231	_	_	0
		Jul-09	31.72	_	433	7.02	5.17	193	20.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Mar-09	29.56	415.6	535	6.86	5.81	92	26.1	68	24	2	12	22	7	230	280.6	<1	<1000	230	109.3	2.83	1.61
GW036151	1	Jul-09	15.61	13933	19000	7.5	6.35	176	18.2	3480	561	6	496	4010	5120	213	259.86	<1	<1000	213	3441	25.81	0.8
	2	Jul-09	25.25	2790	4320	7.68	0	100	21.6	727	126	3	74	1230	396	192	234.24	<1	<1000	192	618.9	12.71	3.02

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW036151	2																						
GW036166	1	Feb-09	24.05	9695	11370	7.18	0.88	103	21.7	2500	302	4	332	1800	4170	481	586.82	<1	<1000	481	2120	23.62	1.21
		Jul-09	23.88	9681	11590	7.2	2.25	14	18.9	2240	300	3	328	1770	4380	541	660.02	<1	<1000	541	2098	21.27	4.34
		Apr-09	19.12	11198	14200	7.19	2.97	97	24.5	2780	428	3	466	1460	5490	468	570.96	<1	<1000	468	2986	22.13	4.52
	2	Jul-09	24.09	6921	8830	7.25	0.45	8	20.4	1660	185	2	234	1510	2620	582	710.04	<1	<1000	582	1425	19.13	3.76
	3	Jul-09	23.88	601.5	831	6.97	0.03	-90	22.7	129	26	1	11	70	37.5	268	326.96	<1	<1000	268	110.1	5.35	1.54
		Apr-09	24.15	–	833	7.01	0.15	-223	23.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036190	1	Jul-09	17.51	1716	2541	7.86	1.44	191	19.4	383	57	2	58	406	355	373	455.06	<1	<1000	373	380.9	8.54	3.89
	2	Jul-09	18.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Jul-09	18.755	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036200	1	Jul-09	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Jul-09	13.96	998.5	1308	6.97	1.18	172	20.5	92	116	1	39	138	59.8	453	552.66	<1	<1000	453	449.9	1.89	4.28
	3	Jul-09	16.56	1060	1413	6.93	0.63	163	19.8	98	126	1	42	186	63.6	445	542.9	<1	<1000	445	487.2	1.93	4.96
GW036202	1	Jul-09	12.75	1614	2661	7.2	0.57	177	17.6	381	94	2	76	663	125	224	273.28	<1	<1000	224	547.3	7.08	3.35
GW036210	1	Feb-09	13.13	3560	5105	6.17	0.05	111	23.3	558	372	3	129	1100	274	921	1123.6	<1	<1000	921	1459	6.35	1.43
		Jul-09	12.39	3825	5480	6.21	0.14	184	20.1	538	422	3	142	1310	190	1000	1220	<1	<1000	1000	1637	5.78	4
		Apr-09	12.91	–	5055	6.23	3.49	149	24.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	Feb-09	17.86	1625	1851	5.88	0.07	109	21.8	161	184	4	49	139	44	856	1044.3	<1	<1000	856	660.7	2.72	3.89
		Jul-09	14.49	1405	1576	5.92	0.12	229	16.4	133	162	3	46	129	41.4	730	890.6	<1	<1000	730	593.5	2.37	3.55
		Apr-09	15.09	–	1988	6.01	0.2	111	22.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036238	1	Feb-09	11.18	547.8	785	6.65	5.59	71	21.9	57	59	1	29	50	81	222	270.84	<1	<1000	222	266.5	1.52	1.91
		Jul-09	10.89	–	727	6.64	4.52	180	20.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Apr-09	11.04	–	774	6.87	6.11	165	23.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Jul-09	12.51	239	283	6.9	0.62	22	20.1	16	26	1	12	6.23	8.15	139	169.58	<1	<1000	139	114.3	0.65	1.55

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW036238	2																						
	3	Feb-09	16.32	309.7	377	5.87	0.16	106	22.4	49	16	2	10	7	11	176	214.72	<1	<1000	176	81.07	2.37	1.23
		Jul-09	13.25	_	590	5.84	0.13	185	20.9	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Apr-09	15.19	_	994	5.8	0.12	-6	27.2	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	4	Jul-09	13.73	_	1850	5.91	0.04	0	20.6	_	_	_	_	_	_	_	_	_	_	_	_	_	_
GW036314	1	Jan-09	26.1	21088	12320	6.77	5.72	96	23.3	6110	685	7	883	9480	3400	429	523.38	<1	<1000	429	5343	36.36	3.61
		Mar-09	26.07	21207	28500	6.74	5.72	94	26.4	6110	595	7	945	10400	2640	418	509.96	<1	<1000	418	5373	36.26	2.35
		Jul-09	26.03	20257	26500	6.9	5.5	102	20.8	6000	607	7	849	9420	2870	413	503.86	<1	<1000	413	5008	36.88	3.97
	2	Jul-09	26.64	2364	3290	7.75	0.36	121	21.6	749	42	2	48	1070	141	256	312.32	<1	<1000	256	302.3	18.74	0.38
	3	Jan-09	27.66	2543	4270	7.47	0.17	32	23.2	815	44	2	47	1180	148	252	307.44	<1	<1000	252	303.2	20.36	0.2
		Mar-09	27.29	_	4361	7.49	1.14	78	26.6	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Jul-09	26.85	2334	3200	7.29	0.29	103	21.6	756	40	2	46	1040	138	256	312.32	<1	<1000	256	289.1	19.34	1.79
GW036415	1	Feb-09	26.35	1162	1476	6.88	5.15	48	22.1	92	139	1	56	69	240	463	564.86	<1	<1000	463	577.3	1.67	1.99
		Apr-09	26.43	_	1512	6.89	5.24	54	26.3	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	3	Feb-09	26.18	536.8	742	7.3	1.69	113	22.8	68	55	1	18	50	41	249	303.78	<1	<1000	249	211.3	2.03	0
		Apr-09	26.31	_	737	7.22	0.24	-37	25.3	_	_	_	_	_	_	_	_	_	_	_	_	_	_
GW036515	1	Feb-09	18.59	1027	1280	7.08	8.04	100	20.3	265	11	_	17	115	22	489	596.58	<1	<1000	489	97.4	11.68	0.12
		Jul-09	18.52	_	1210	7.69	7.28	164	19.5	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Apr-09	18.63	_	1305	7.88	7.78	-15	23.7	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	3	Feb-09	25.92	792.8	933	7.48	0.22	-227	21.3	127	31	4	32	49	2	449	547.78	<1	<1000	449	209	3.82	2.95
		Jul-09	21.05	_	879	7.49	0.14	-155	20.5	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Apr-09	26.12	_	955	7.64	0.2	-250	23.6	_	_	_	_	_	_	_	_	_	_	_	_	_	_
GW036541	1	Jan-09	19.47	10544	10170	7.17	0.45	44	24	3110	259	6	285	4900	1620	298	363.56	<1	<1000	298	1819	31.72	1.72
		Mar-09	19.46	10371	16200	7.19	0.41	-113	24.7	3310	269	6	332	4930	1140	315	384.3	<1	<1000	315	2037	31.90	4.43

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW036541	1																						
		Jul-09	19.46	10234	14910	7.29	0.35	27	20.8	3030	274	6	315	4840	1360	335	408.7	<1	<1000	335	1980	29.62	0.04
	2	Jan-09	–	1758	–	–	–	–	–	586	16	2	12	600	103	360	439.2	<1	<1000	360	89.3	26.97	1.97
	3	Jan-09	18.89	–	2805	7.31	0.17	-135	23.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Mar-09	18.88	–	2854	7.36	0.54	-132	22.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	18.88	1725	2430	7.68	0.32	128	20.2	574	17	2	13	619	80	344	419.68	<1	<1000	344	95.91	25.49	1.7
GW036566	1	Feb-09	7.6	950.2	1380	7.32	6.42	49	20.8	121	53	3	60	214	10	401	489.22	<1	<1000	401	379.1	2.70	4.94
		Jul-09	7.71	2451	1366	7.34	6.2	15	19.7	1341	6768	3	7071	240249	0	373399	0	<1	<1000	373399	–	–	0
		Apr-09	7.65	–	1310	7.45	6.1	108	23.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036600	1	Jul-09	14.75	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Jul-09	14.75	2126	2590	7.06	0.06	-147	20.9	489	59	7	71	428	61.1	829	1011.4	<1	<1000	829	439.4	10.15	0.5
	3	Feb-09	23.26	2667	3838	7.03	0.09	-104	21.1	652	75	10	90	820	55	791	965.02	<1	<1000	791	557.5	12.01	0.41
		Jul-09	14.91	2785	3730	7.04	0.13	-109	20.9	667	92	10	112	888	75.1	771	940.62	<1	<1000	771	690.4	11.04	1.25
		Apr-09	18.35	–	4091	7.11	0.04	-195	23.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036602	1	Feb-09	14.86	2137	3441	7.38	0.08	-128	22.1	622	39	3	56	787	140	402	490.44	<1	<1000	402	327.8	14.94	0.8
		Jul-09	15.83	2148	3440	7.44	0.13	-177	19.4	602	42	3	62	943	142	290	353.8	<1	<1000	290	359.9	13.80	2.8
		Apr-09	14.99	–	3900	7.39	0.37	-115	24.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	Feb-09	–	3973	–	–	–	–	–	1140	58	8	121	1480	358	662	807.64	<1	<1000	662	642.7	19.56	0.12
		Jul-09	14.42	3267	4760	7.29	0.14	-144	19.3	892	66	6	128	1230	434	419	511.18	<1	<1000	419	691.4	14.76	0.52
	3	Feb-09	20.76	–	5895	7.36	0.06	-229	21.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Jul-09	14.43	3715	5360	7.47	0.11	-239	19.5	1070	59	7	128	1320	401	598	729.56	<1	<1000	598	674	17.93	2.33
		Apr-09	18	–	5579	7.38	0.24	-246	22.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GW036654	1	Feb-09	3.24	594.8	800	7.47	5	39	19.9	49	38	2	48	63	2	322	392.84	<1	<1000	322	292.3	1.25	1.31
		Jul-09	3.49	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Loc Code	Pipe	Sampled Date	SWL (m TOC)	TDS (mg/L)	EC (µS/cm)	pH	DO (mg/L)	Eh(mV)	Temp(°C)	Sodium (mg/L)	Calcium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Bicarbonate as CaCO3 (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Alkalinity (Hydroxide) as CaCO3 (µg/L)	Alkalinity (total) as CaCO3 (mg/L)	Hardness as CaCO3 (mg/L)	SAR	Ionic Balance (%)
GW036654	1																						
		Apr-09	3.64	_	817	7.82	4.84	139	21.3	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	2	Feb-09	3.38	535.1	690	7.52	3.54	33	20.2	43	36	2	41	50	2	296	361.12	<1	<1000	296	258.5	1.16	1.94
		Jul-09	3.56	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Apr-09	3.72	_	720	7.65	3.23	125	23.7	_	_	_	_	_	_	_	_	_	_	_	_	_	_
GW040822	1	Feb-09	2.44	5457	9694	7.73	0.05	-101	20.7	1550	108	4	273	2760	462	246	300.12	<1	<1000	246	1393	18.06	1.58
		Jul-09	3.11	4237	7860	7079	0.01	-54	19.3	1200	84	3	217	2000	426	252	307.44	<1	<1000	252	1103	15.72	2.7
		Apr-09	2.9	_	9307	7.69	0.13	-63	21.8	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	2	Jul-09	3.1	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	3	Jul-09	2.49	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
	4	Feb-09	2.37	1091	1622	7.71	0.05	-227	21.6	292	15	6	19	286	3	385	469.7	<1	<1000	385	115.6	11.81	2.29
		Jul-09	2.395	_	1417	7.74	0.05	-169	21.6	_	_	_	_	_	_	_	_	_	_	_	_	_	_
		Apr-09	2.39	_	1585	7.64	0.15	-196	22.1	_	_	_	_	_	_	_	_	_		_	_	_	_

WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 1
UPPER MONITORING UNIT, UPPER NAMOI

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

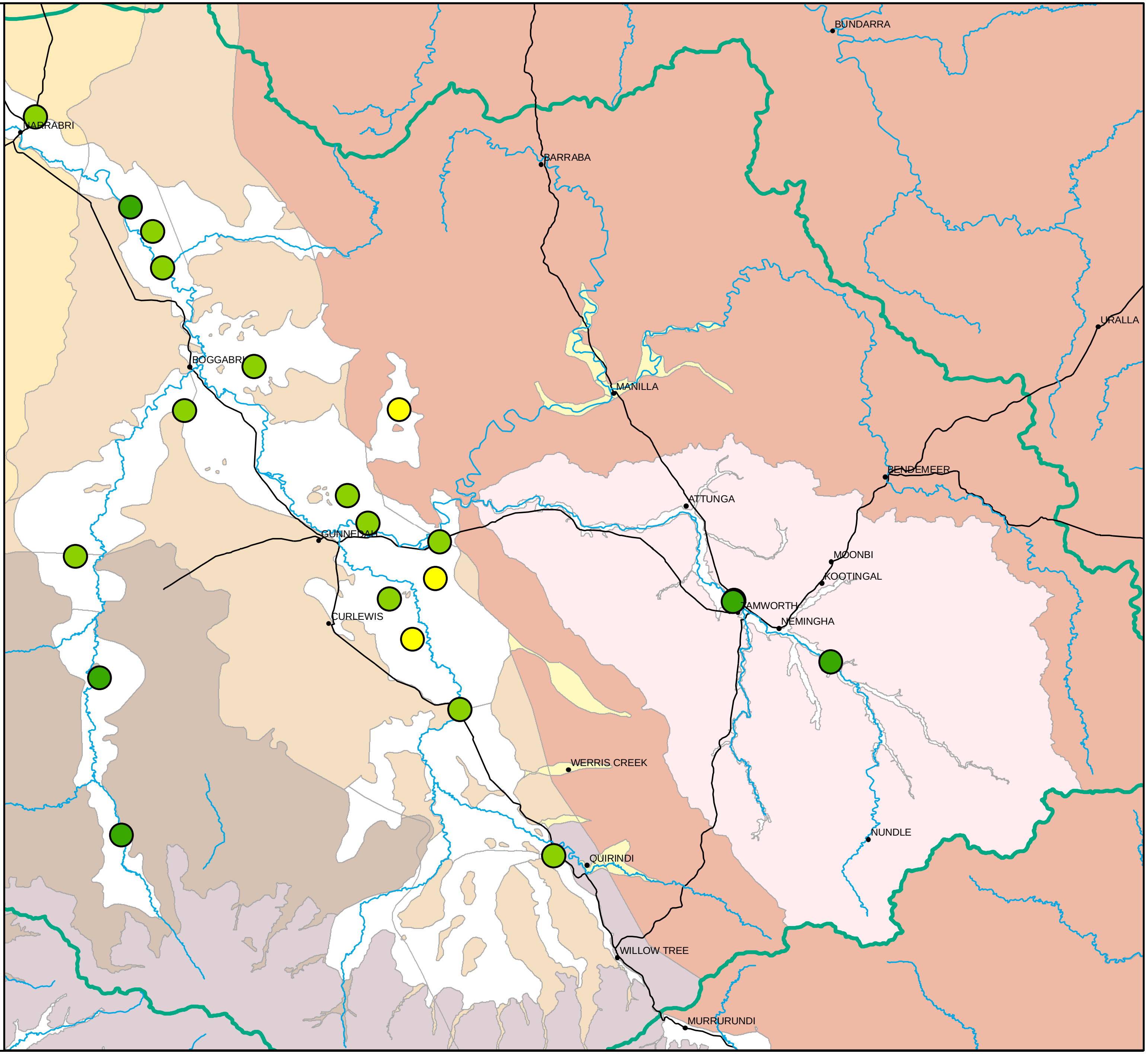


Figure A7.1

Namoi_6_7.mxd

WRL

Report No. 2009/25

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

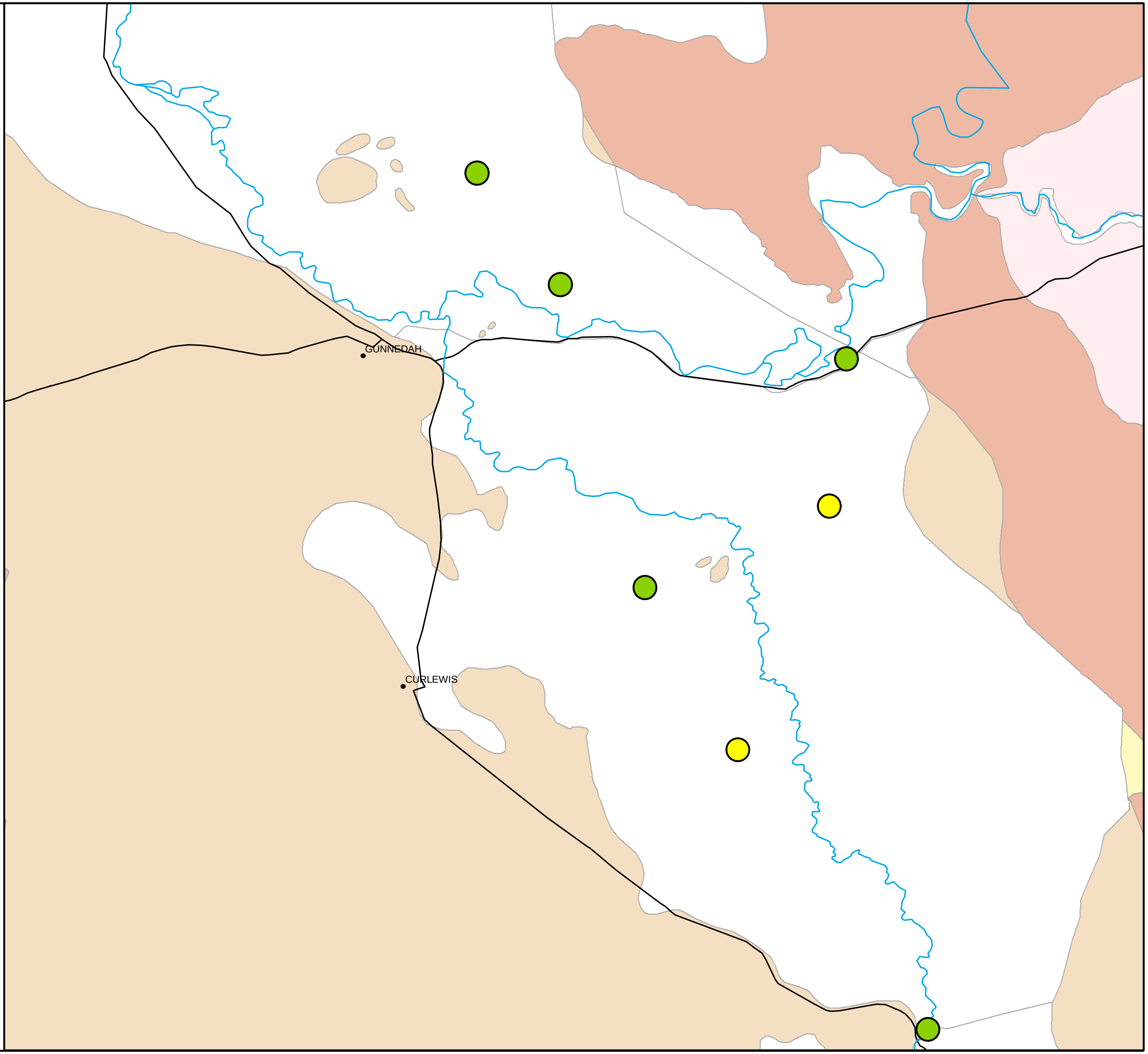
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



SWL (mbg) - WRL MONITORING ROUND 1

UPPER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure A7.2

Namoi_6_7.mxd

WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 1
UPPER MONITORING UNIT, LOWER NAMOI

Figure A7.3

Namoi_6_7.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

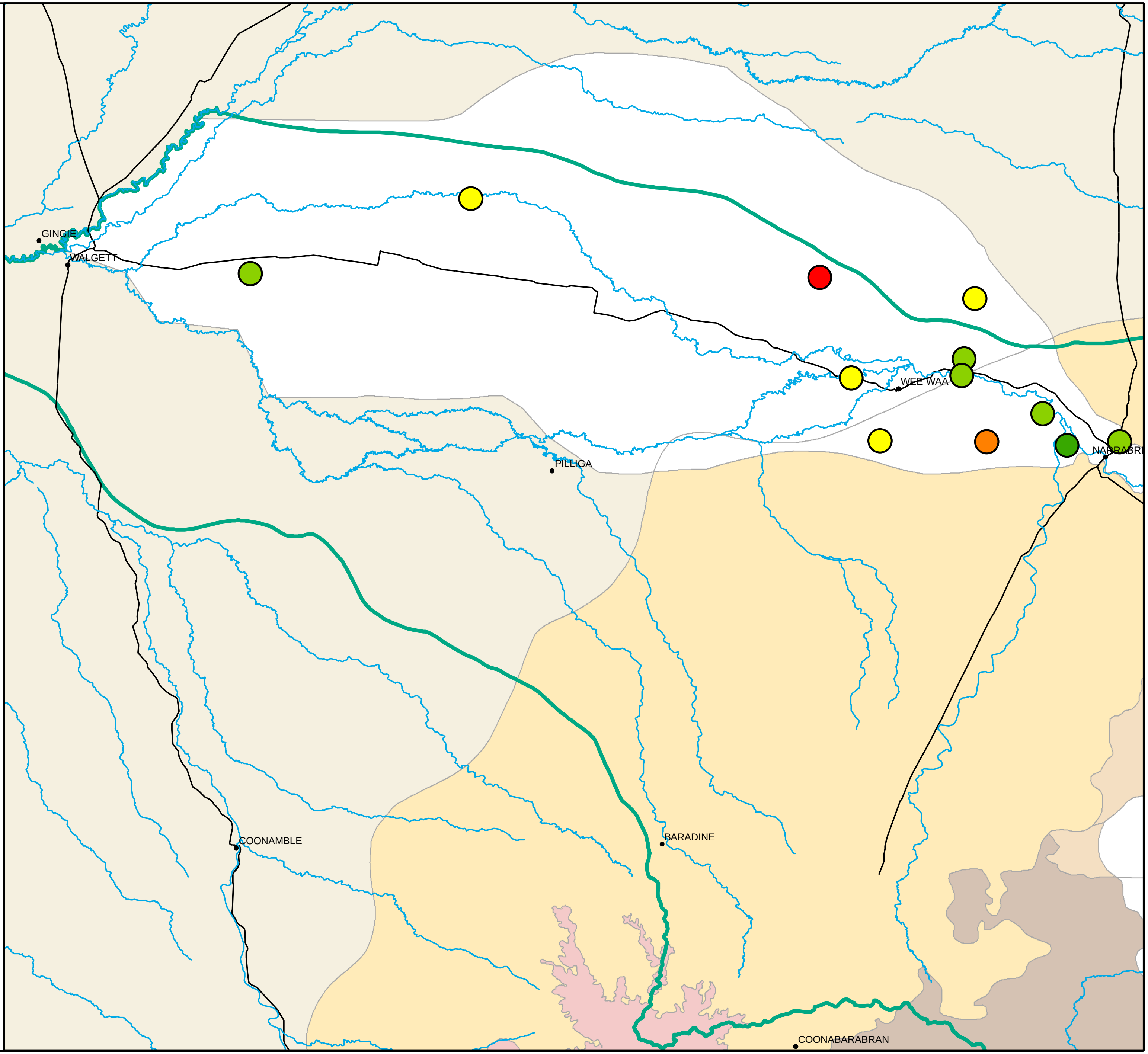
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 2
UPPER MONITORING UNIT, UPPER NAMOI

Figure A7.4

Namoi_6_8.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

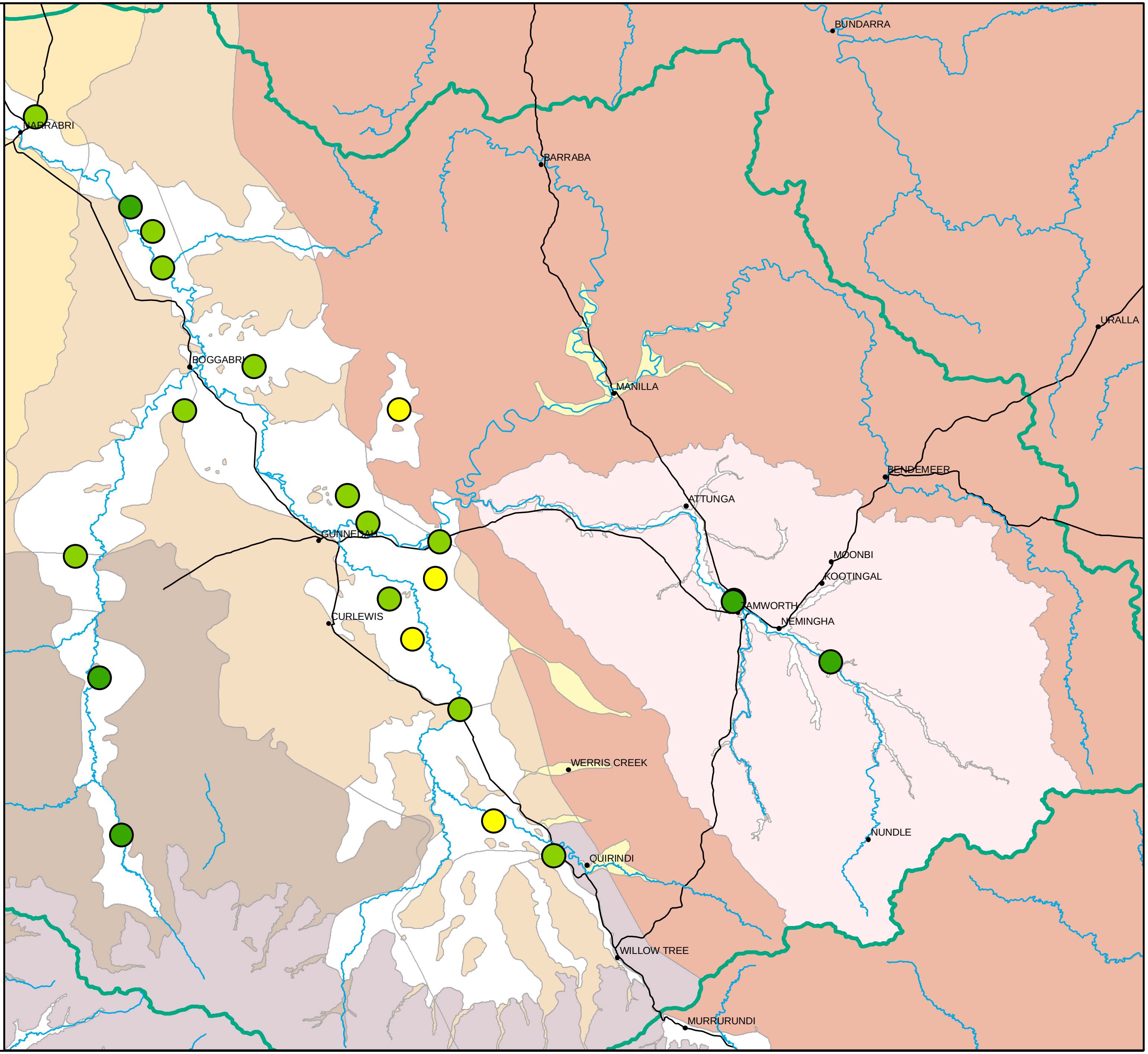
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 2
UPPER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure
A7.5

Namoi_6_8.mxd

2

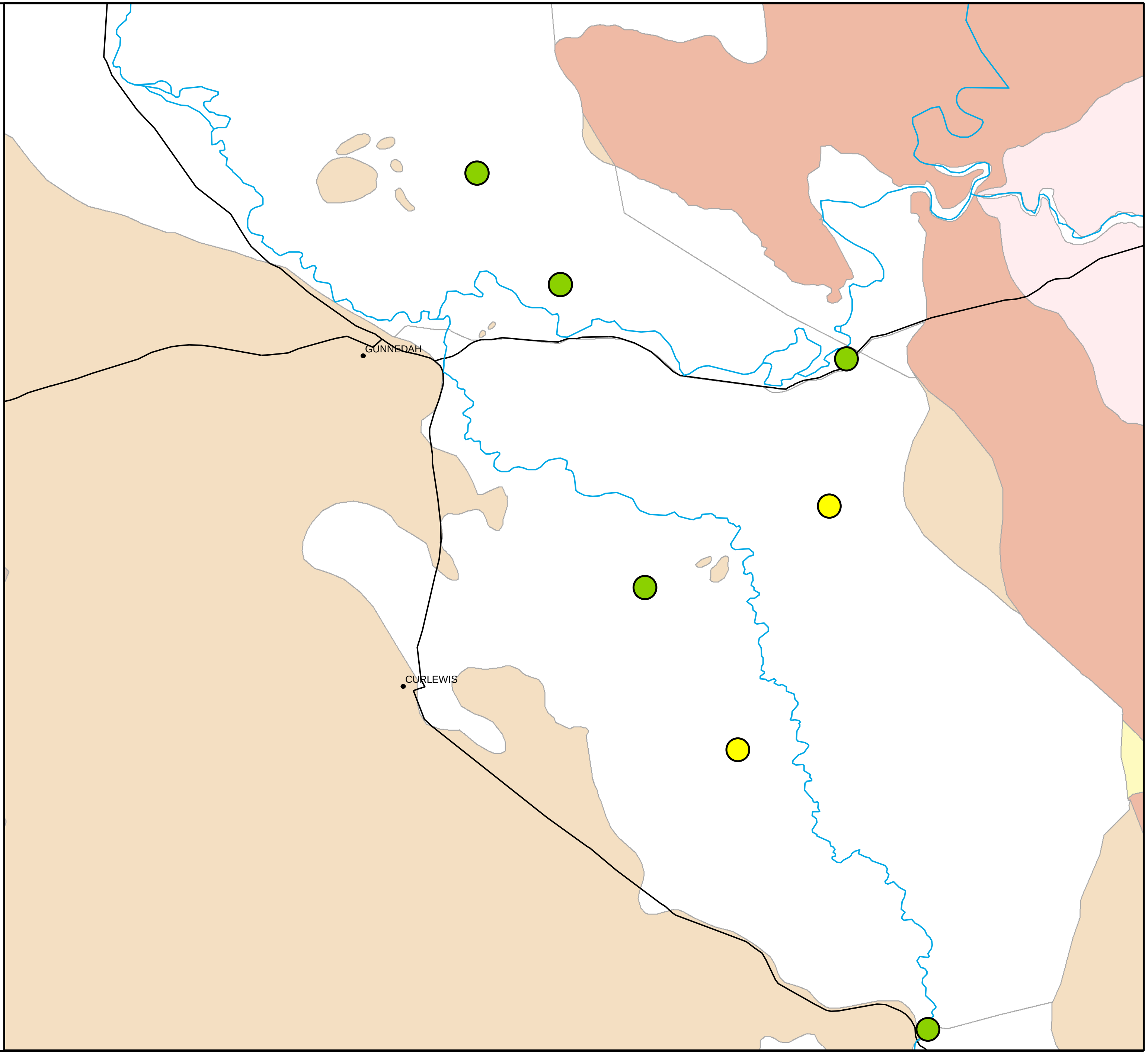
0 2 4 8 Kilometres

GDA94 (Lat/Long)

Legend

SWL (mbg)
- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA
- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

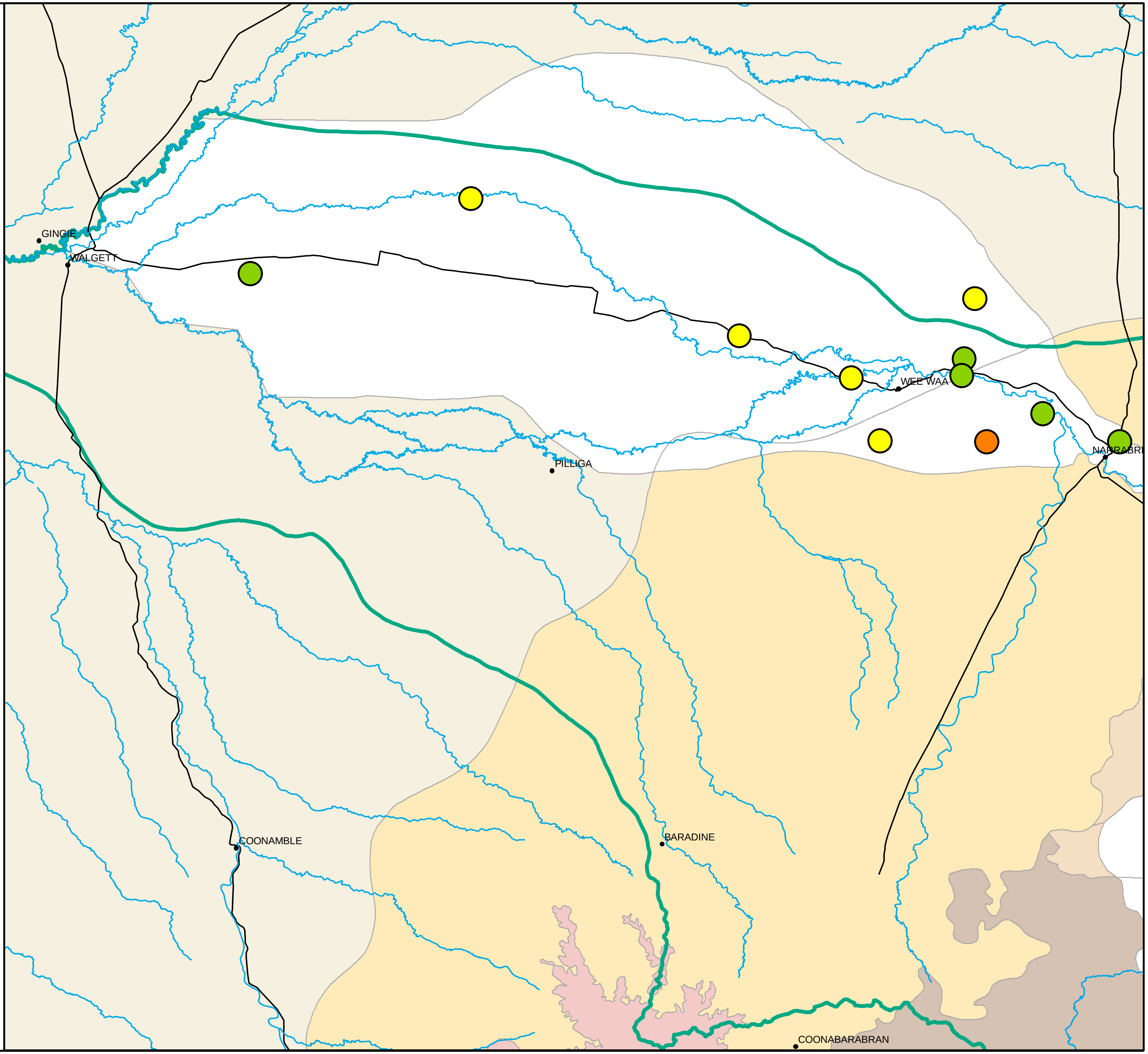


WRL
Report No. 2009/25

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)



Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

SWL (mbg) - WRL MONITORING ROUND 2
UPPER MONITORING UNIT, LOWER NAMOI

Figure
A7.6

Namoi_6_8.mxd

WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 3
UPPER MONITORING UNIT, UPPER NAMOI

Figure
A7.7

Namoi_6_9.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

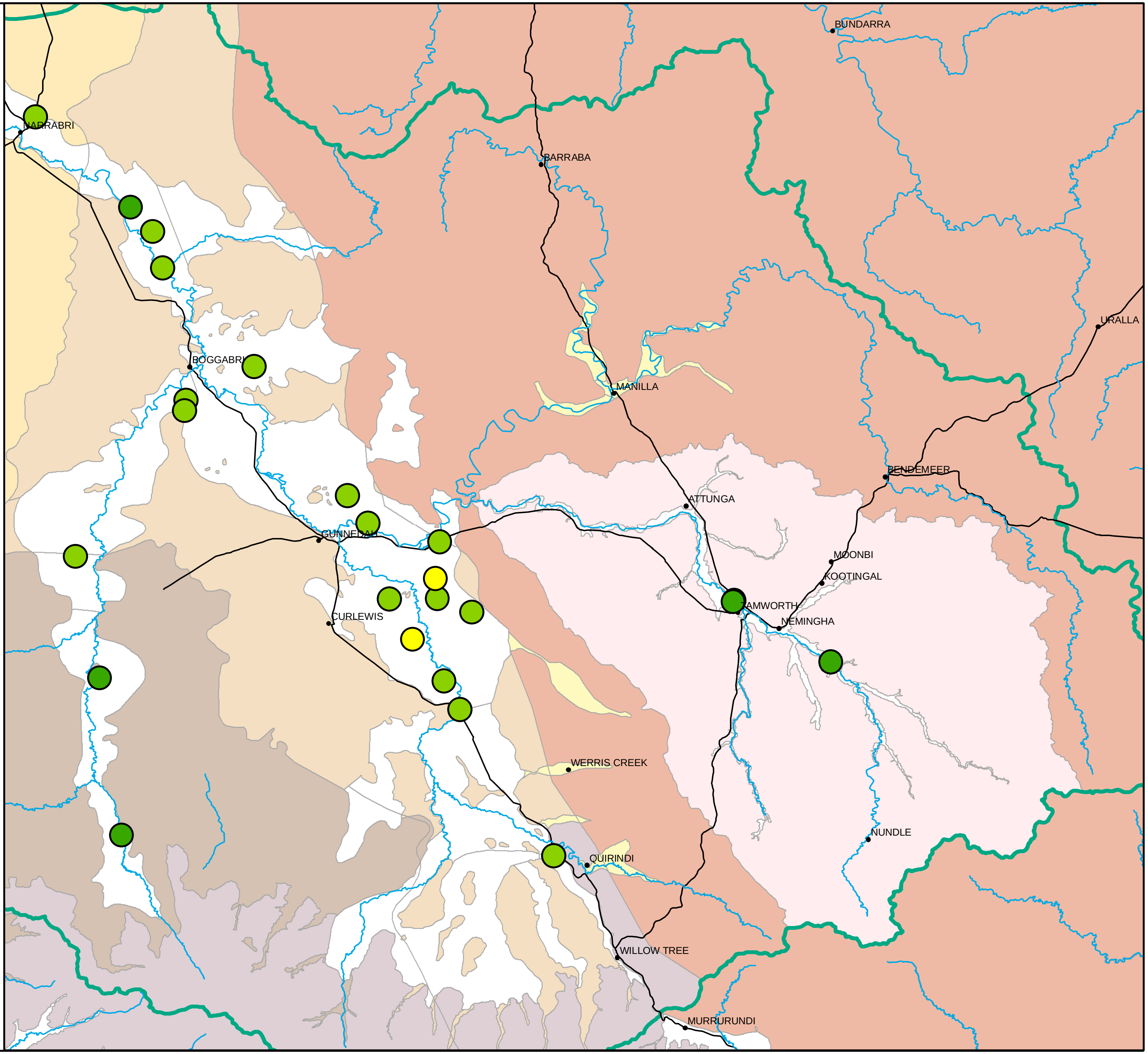
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 3

UPPER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure

A7.8

Namoi_6_9.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

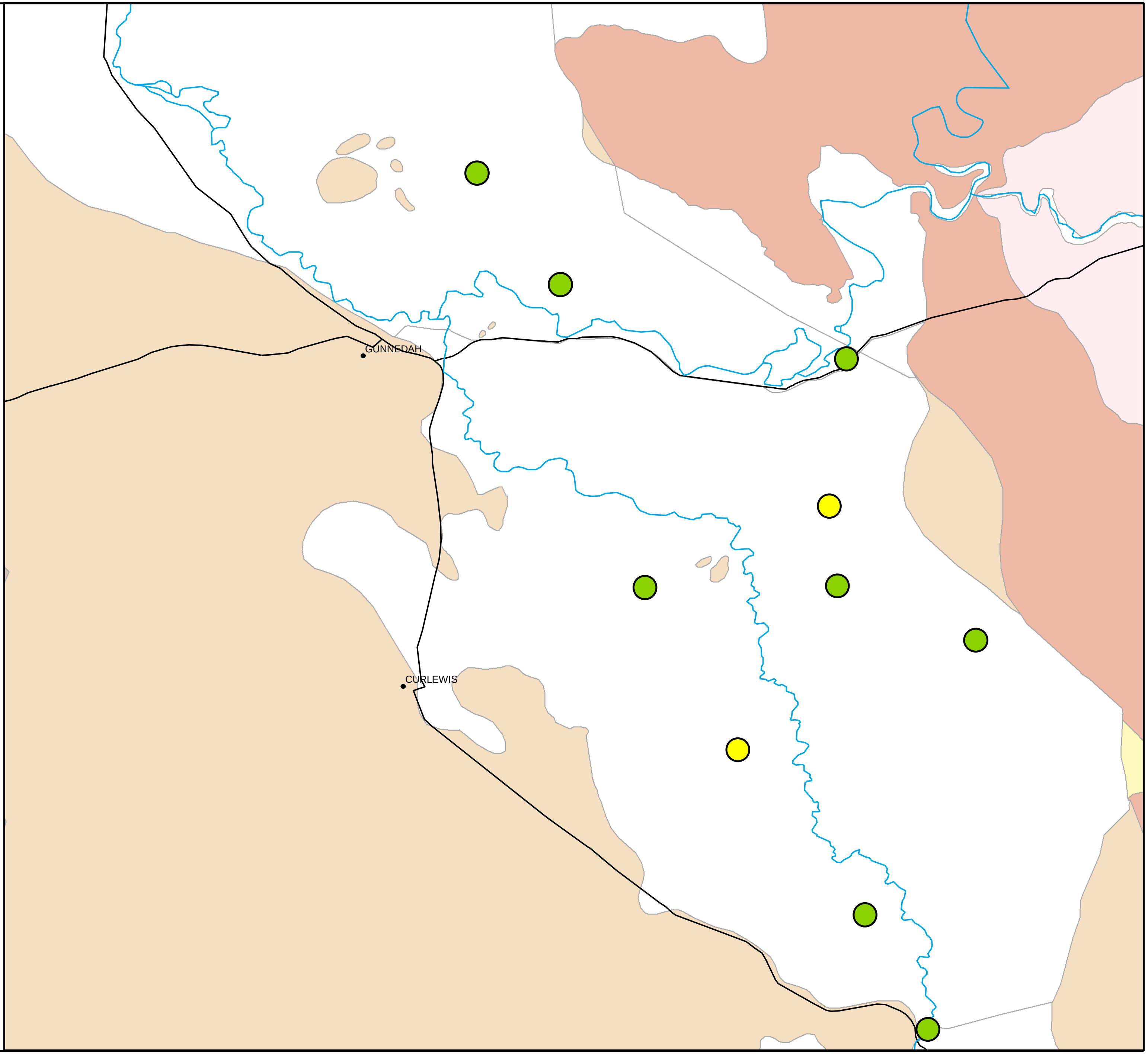
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 3
UPPER MONITORING UNIT, LOWER NAMOI

Figure
A7.9

Namoi_6_9.mxd

2

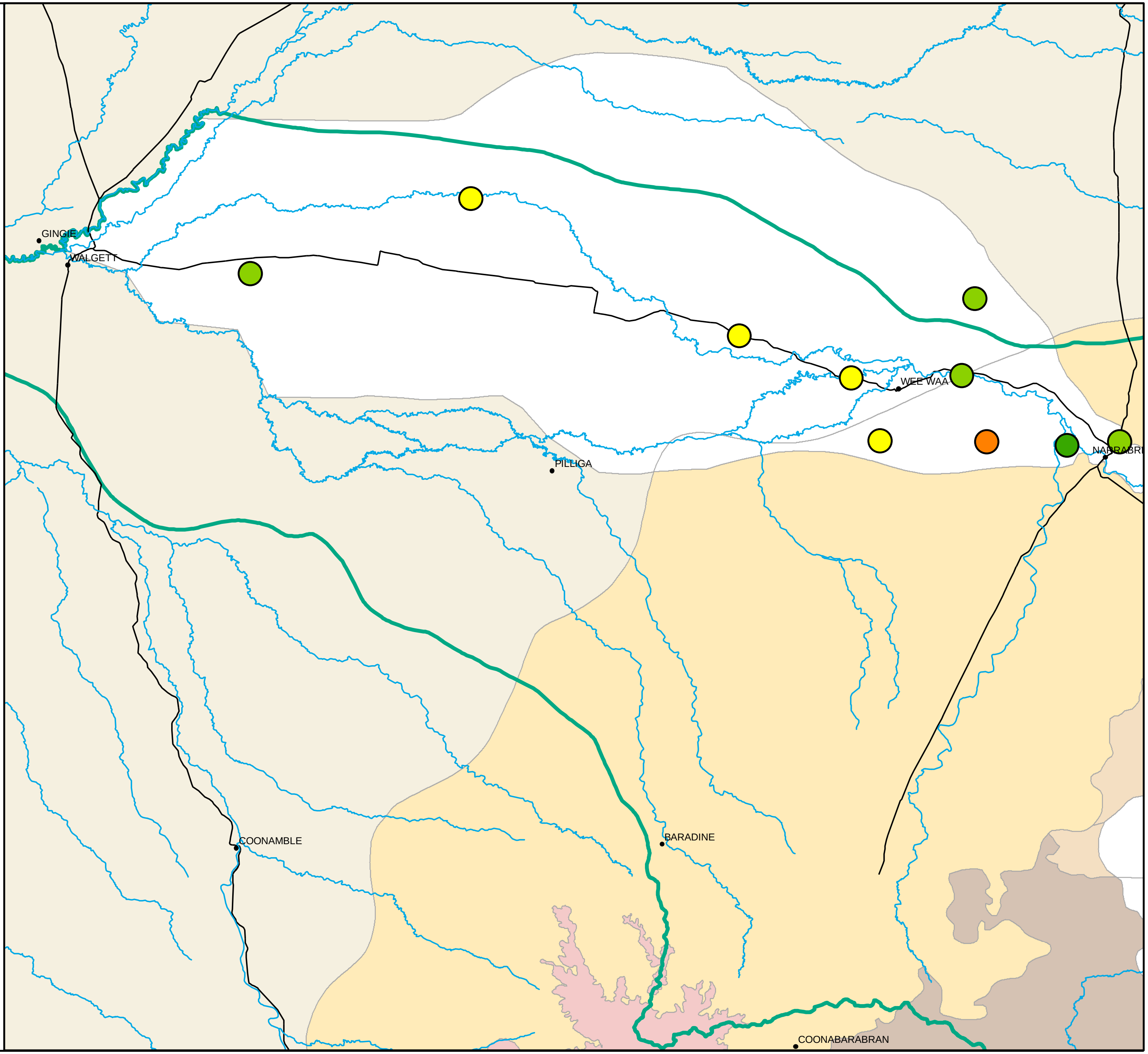
0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

SWL (mbg)
- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA
- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 1
LOWER MONITORING UNIT, UPPER NAMOI

Figure
A7.10

Namoi_6_10.mxd

2

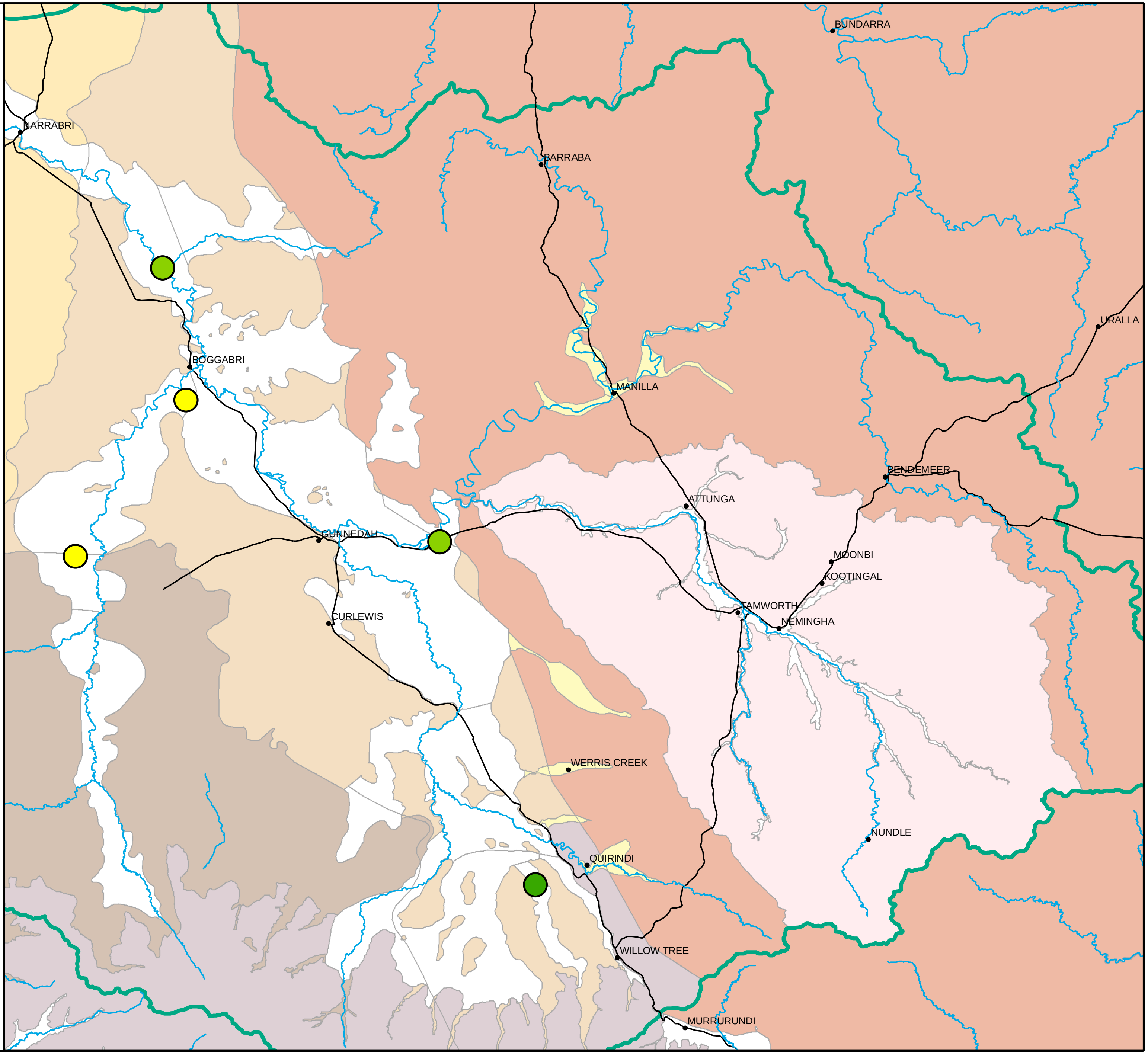
0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

SWL (mbg)
- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA
- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL
Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 1
LOWER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure
A7.11

Namoi_6_10.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

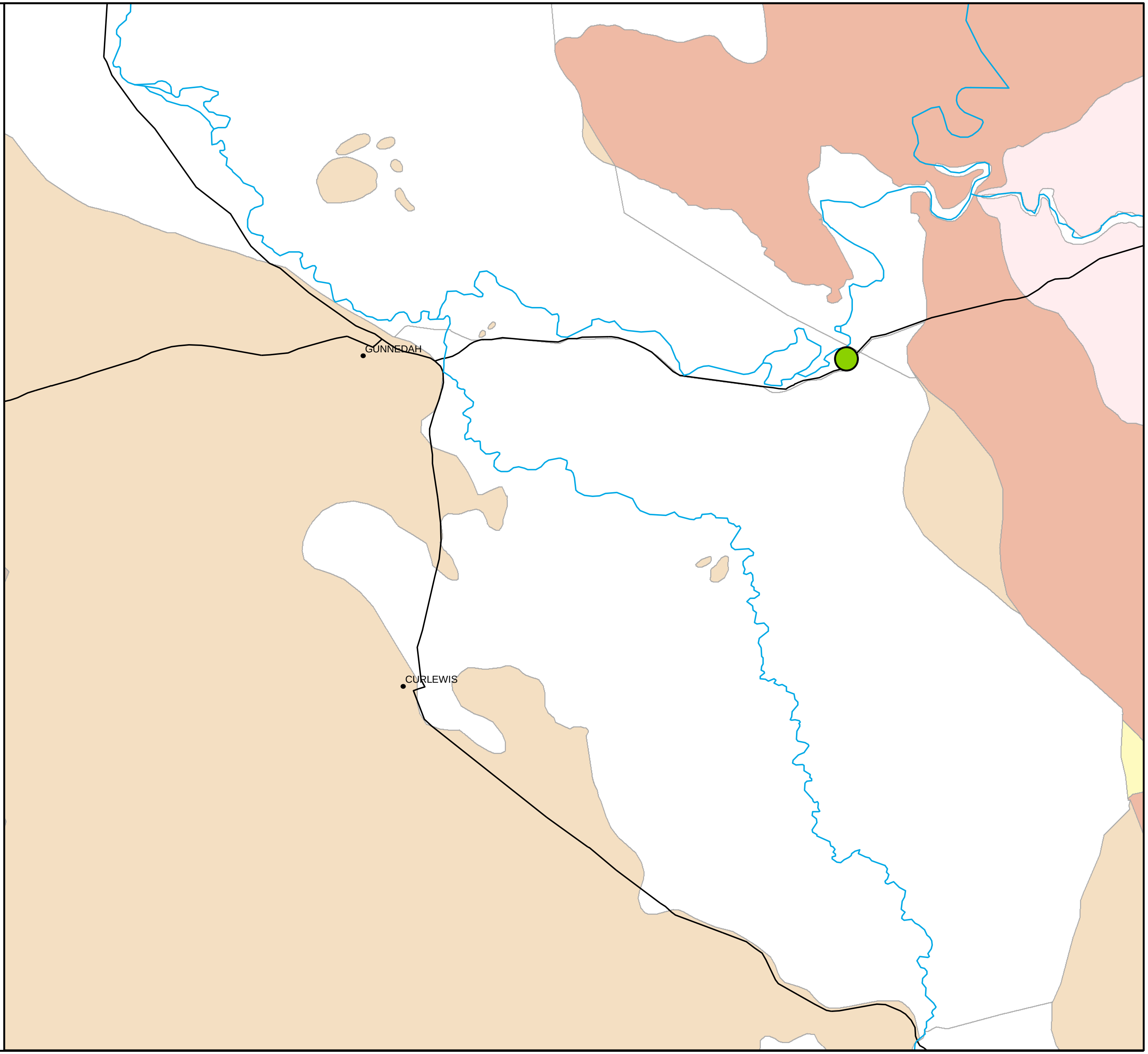
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 1

LOWER MONITORING UNIT, LOWER NAMOI

Figure

A7.12

Namoi_6_10.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

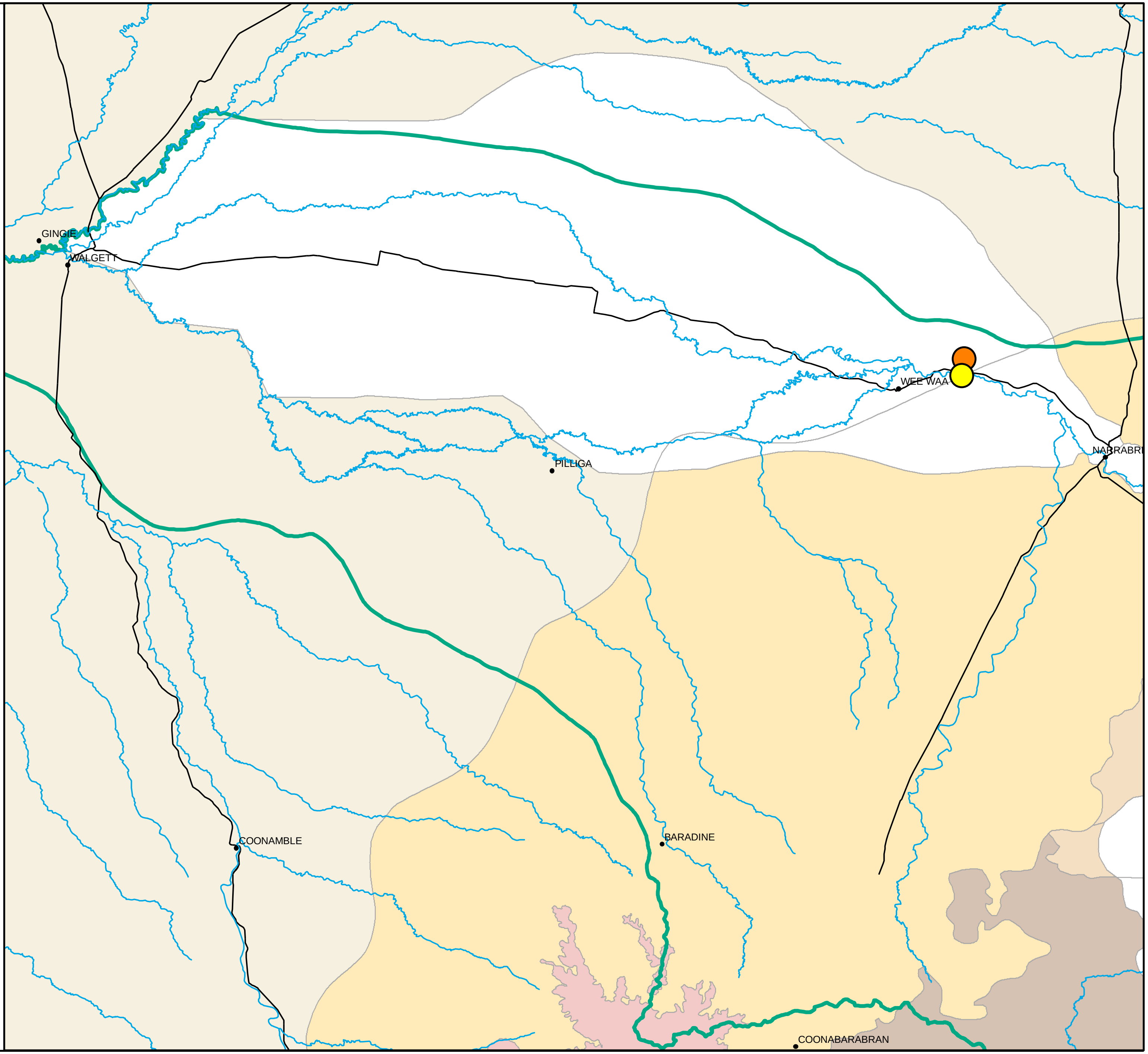
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 2
LOWER MONITORING UNIT, UPPER NAMOI

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

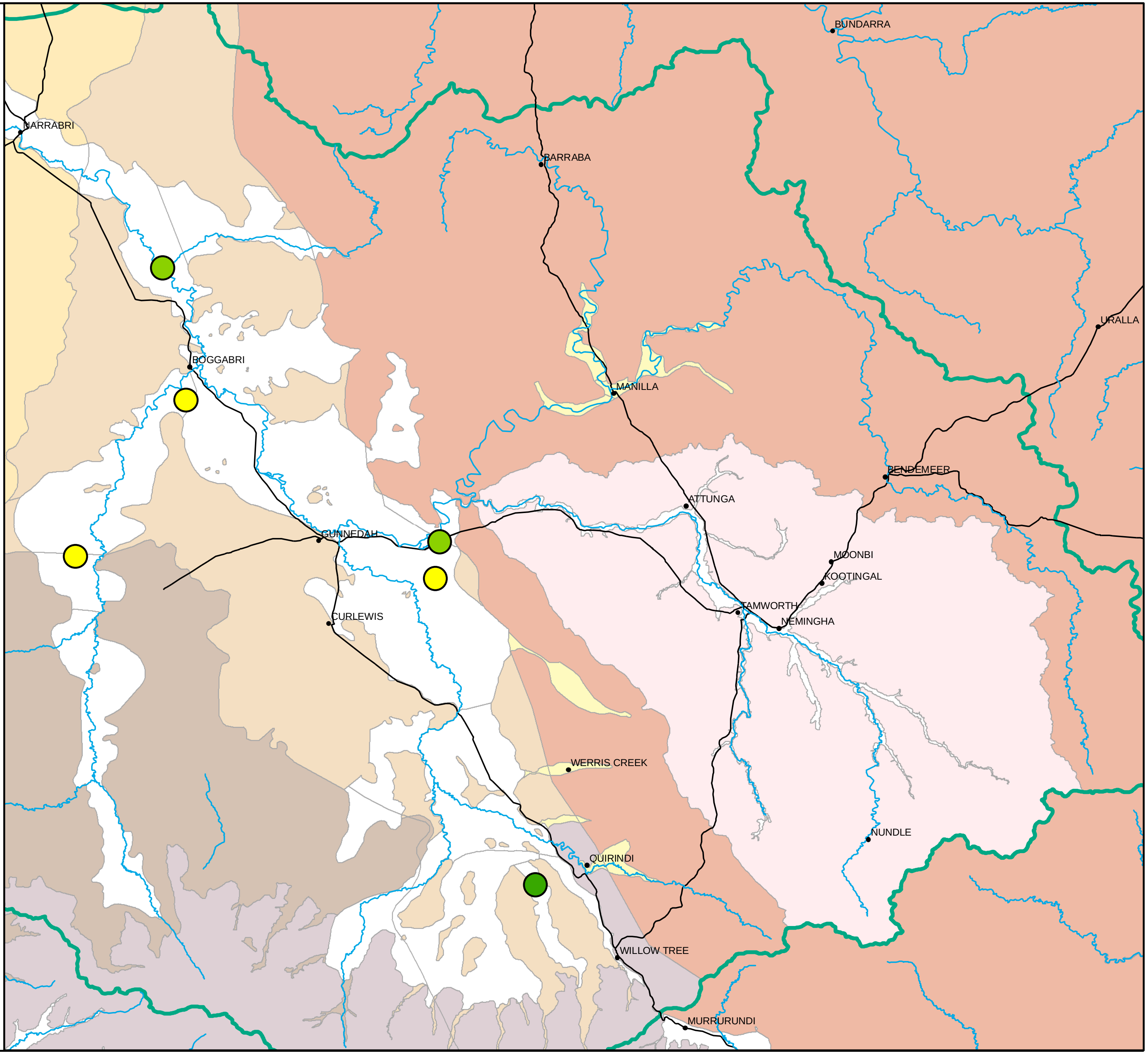


Figure A7.13

Namoi_6_11.mxd

WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 2
LOWER MONITORING UNIT, UPPER NAMOI ZONE 3

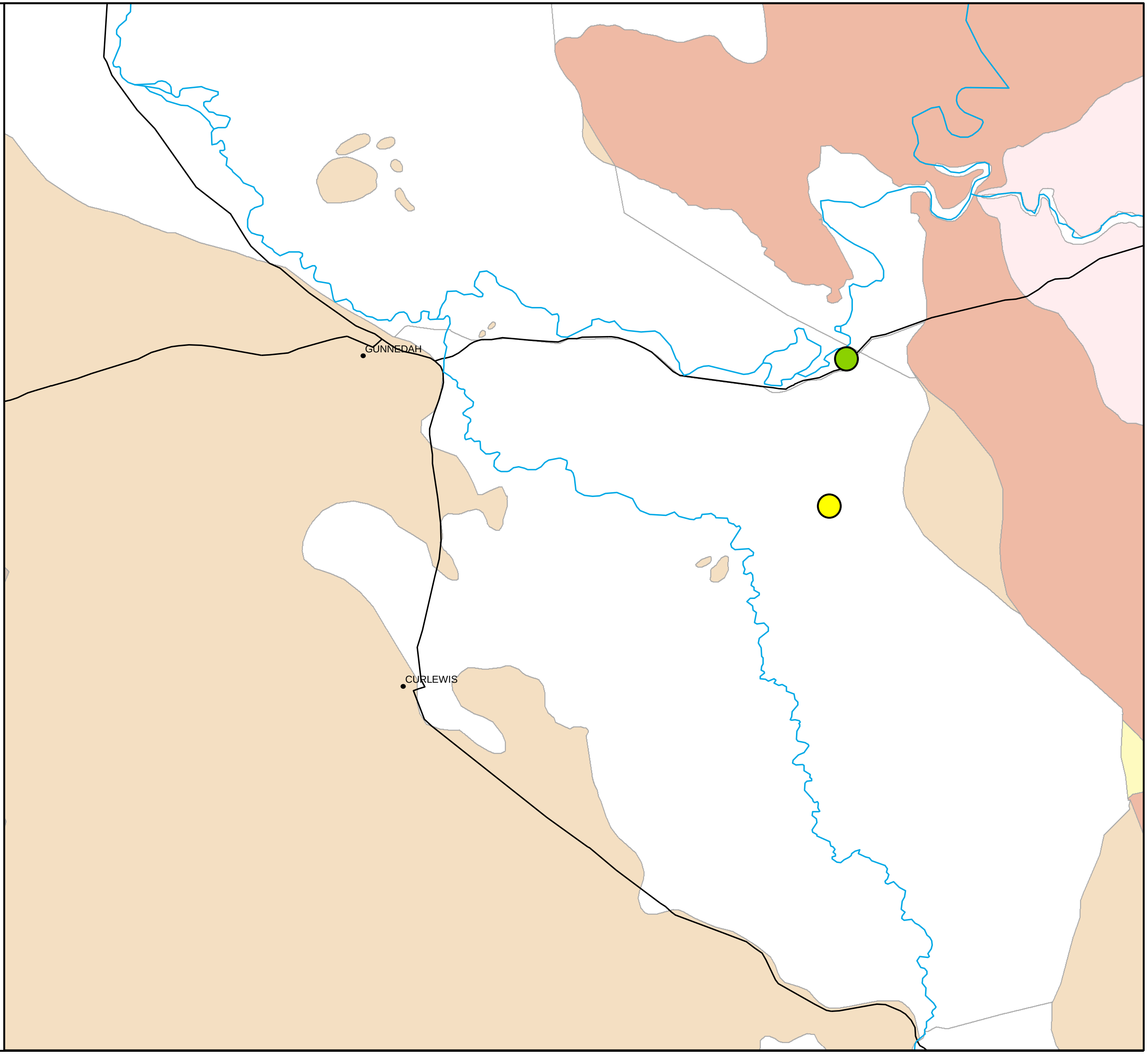
Figure A7.14

Namoi_6_11.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)



Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 2

LOWER MONITORING UNIT, LOWER NAMOI

Figure

A7.15

Namoi_6_11.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

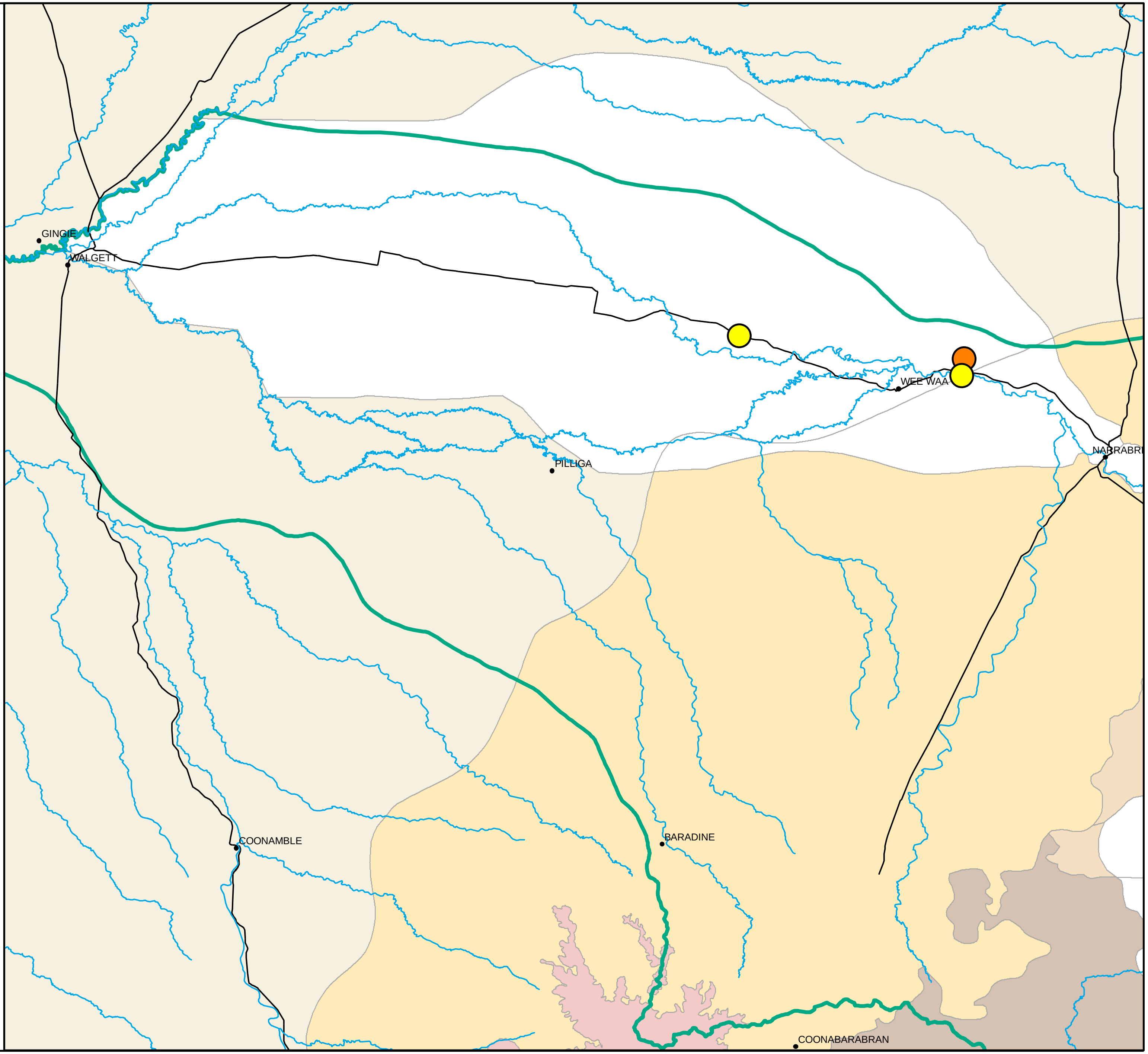
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 3
LOWER MONITORING UNIT, UPPER NAMOI

Figure A7.16

Namoi_6_12.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

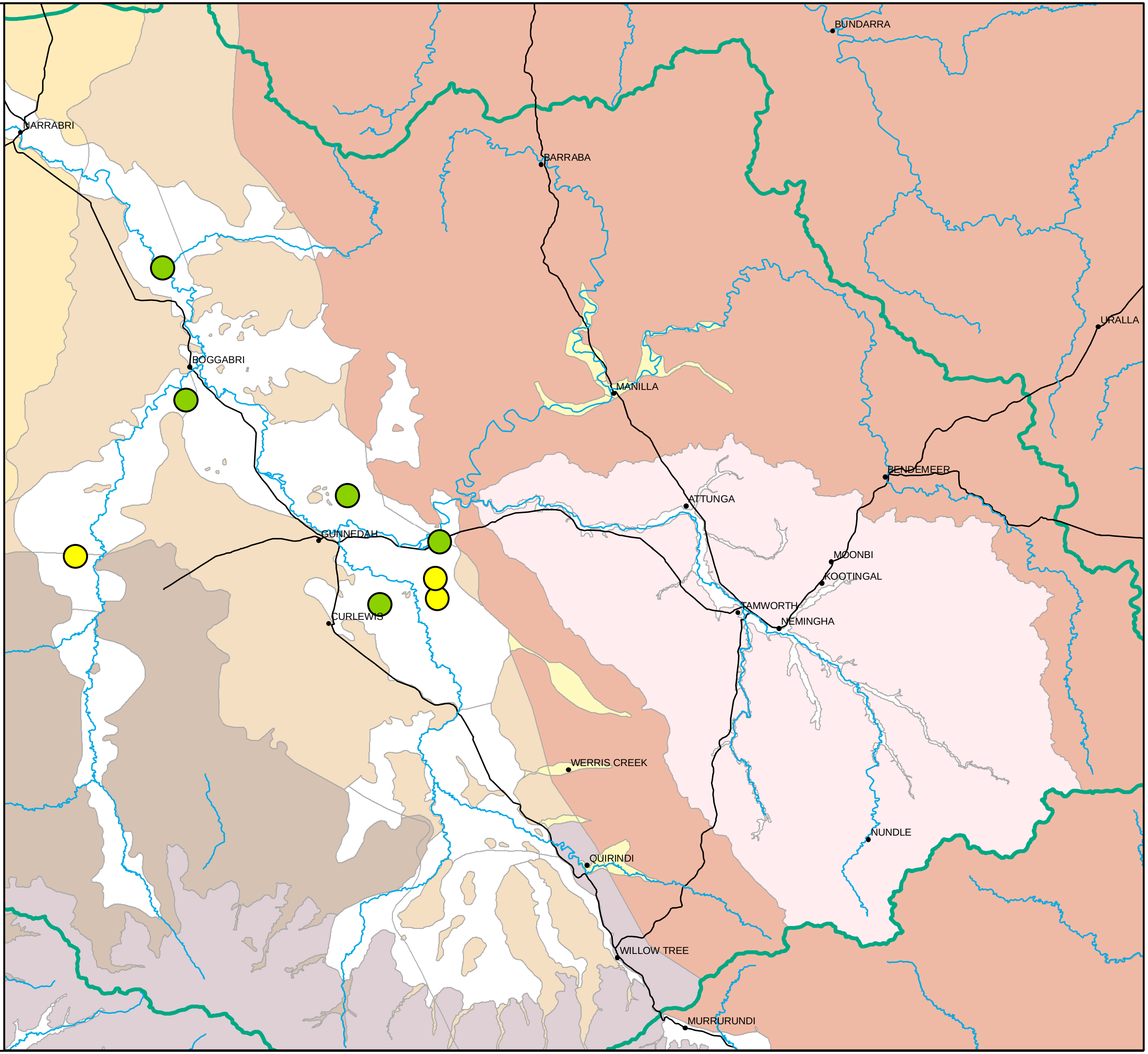
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SWL (mbg) - WRL MONITORING ROUND 3

LOWER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure

A7.17

Namoi_6_12.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

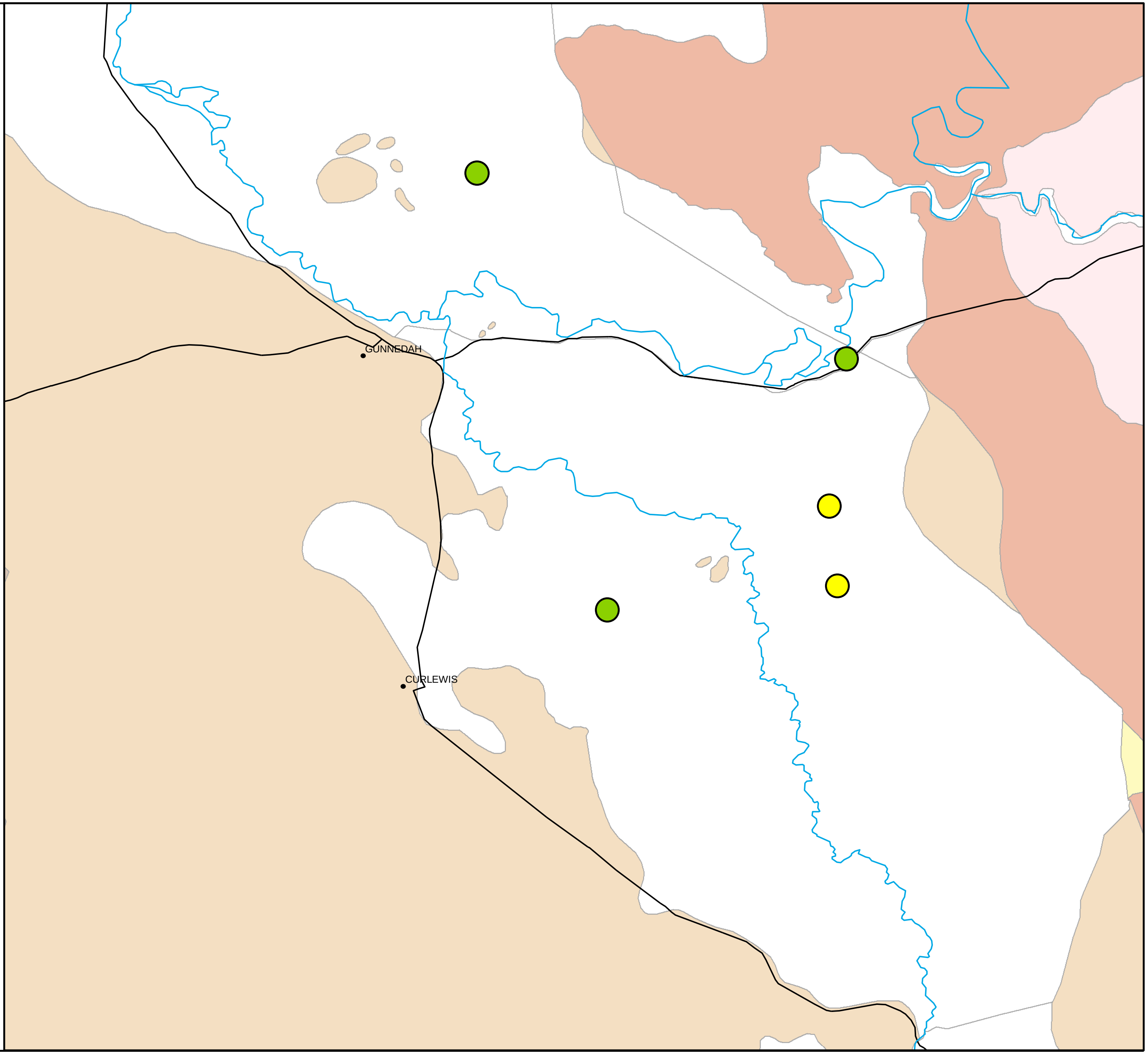
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

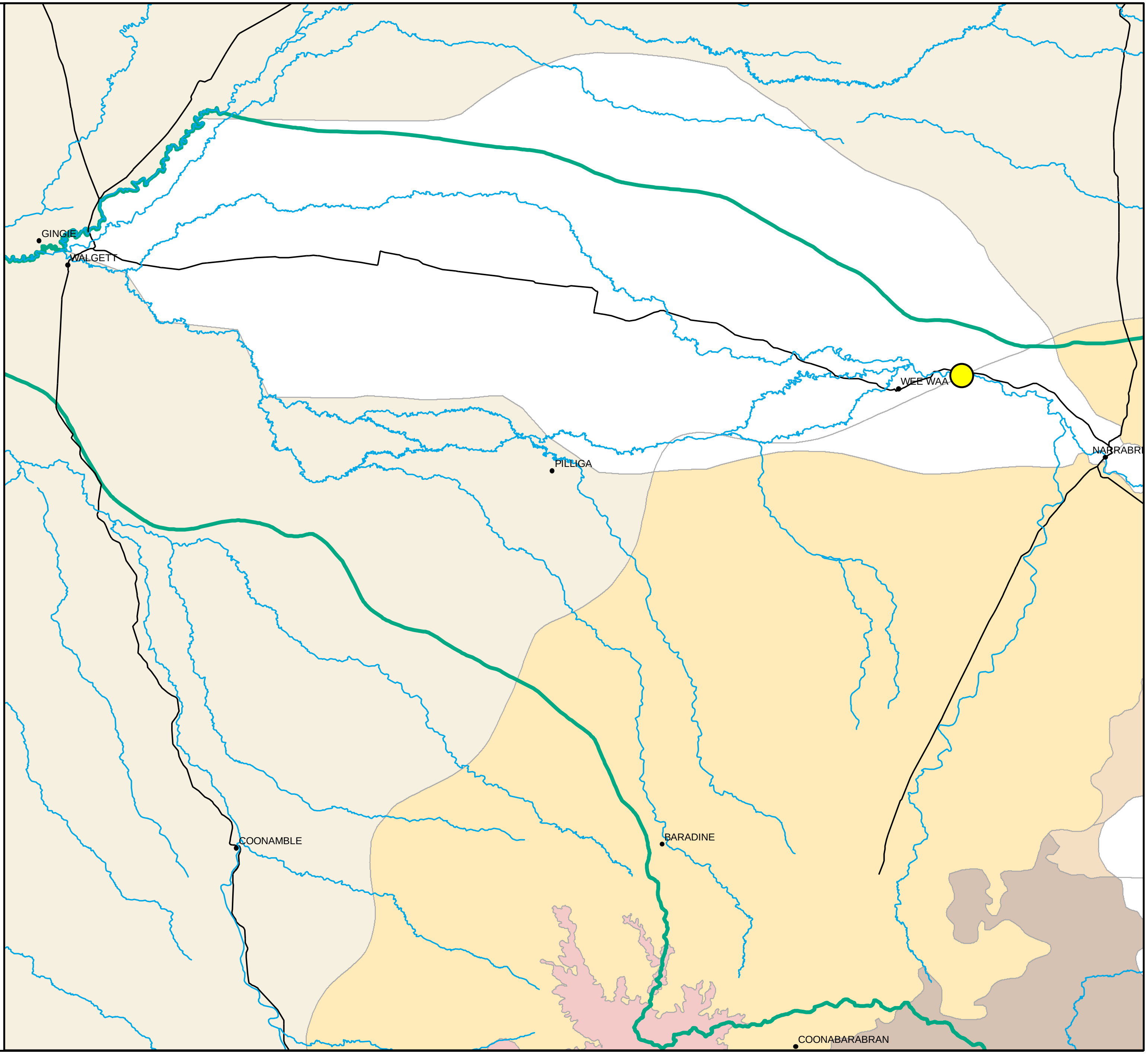
Legend

SWL (mbg)

- <10
- 11 - 20
- 21 - 30
- 31 - 40
- >40
- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL
Report No. 2009/25

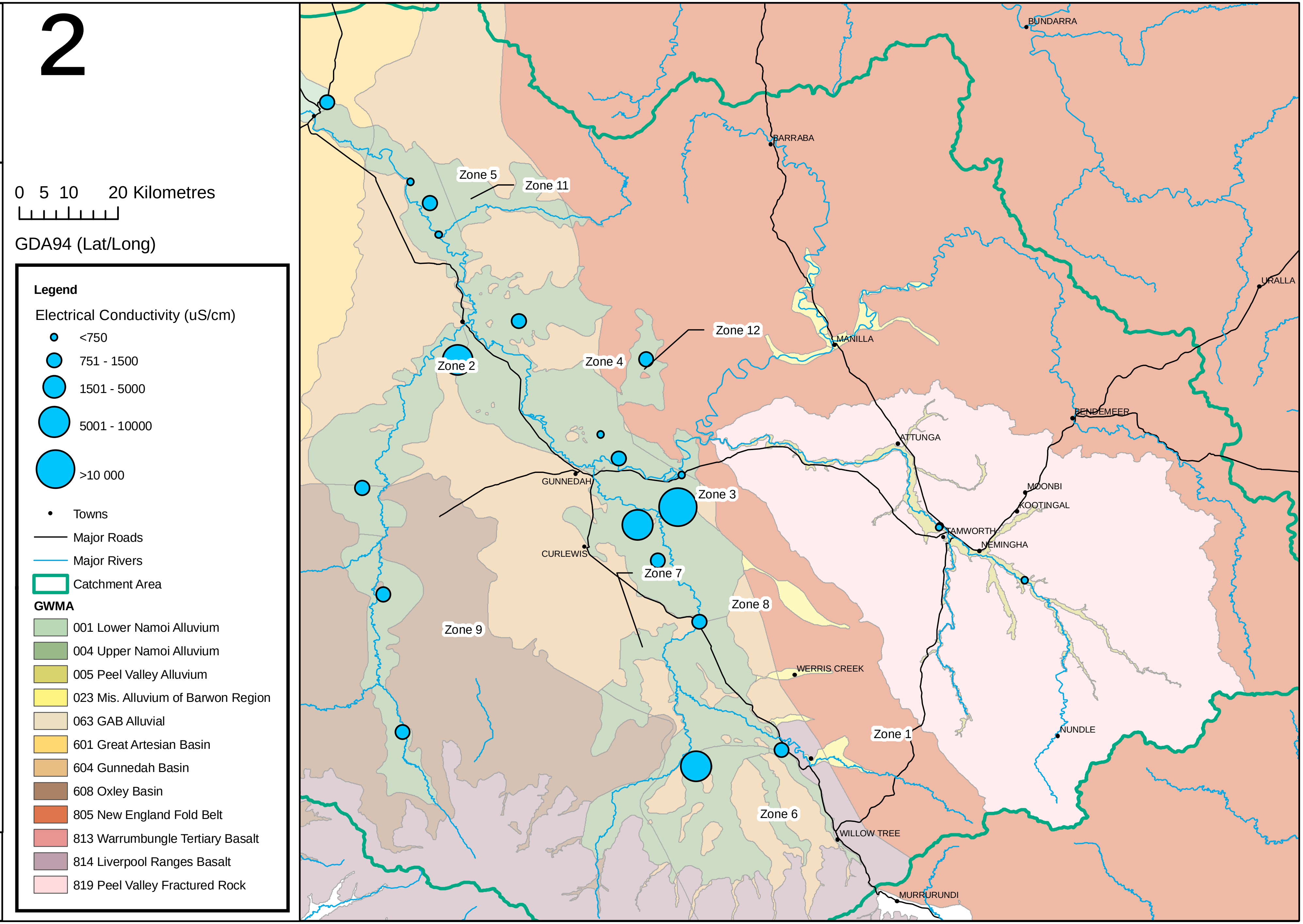
SWL (mbg) - WRL MONITORING ROUND 3
LOWER MONITORING UNIT, LOWER NAMOI

Figure
A7.18

Namoi_6_12.mxd

WRL

Report No. 2009/25



SALINITY - WRL MONITORING ROUND 1

UPPER MONITORING UNIT, UPPER NAMOI

Figure A7.19

Namoi_6_1.mxd

WRL
Report No. 2009/25

SALINITY - WRL MONITORING ROUND 1
UPPER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure
A7.20

Namoi_6_1.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

Legend

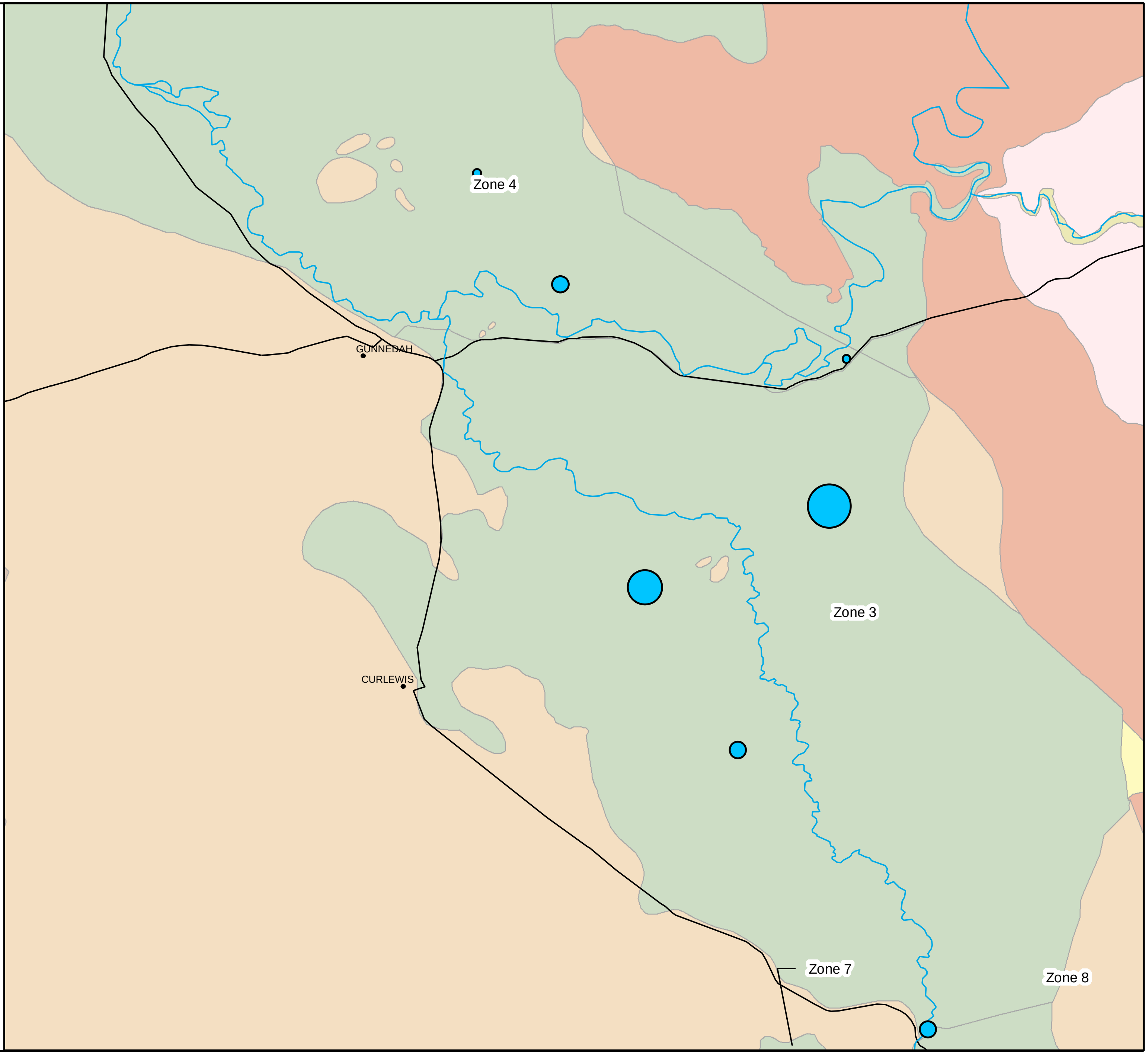
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 1

UPPER MONITORING UNIT, LOWER NAMOI

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

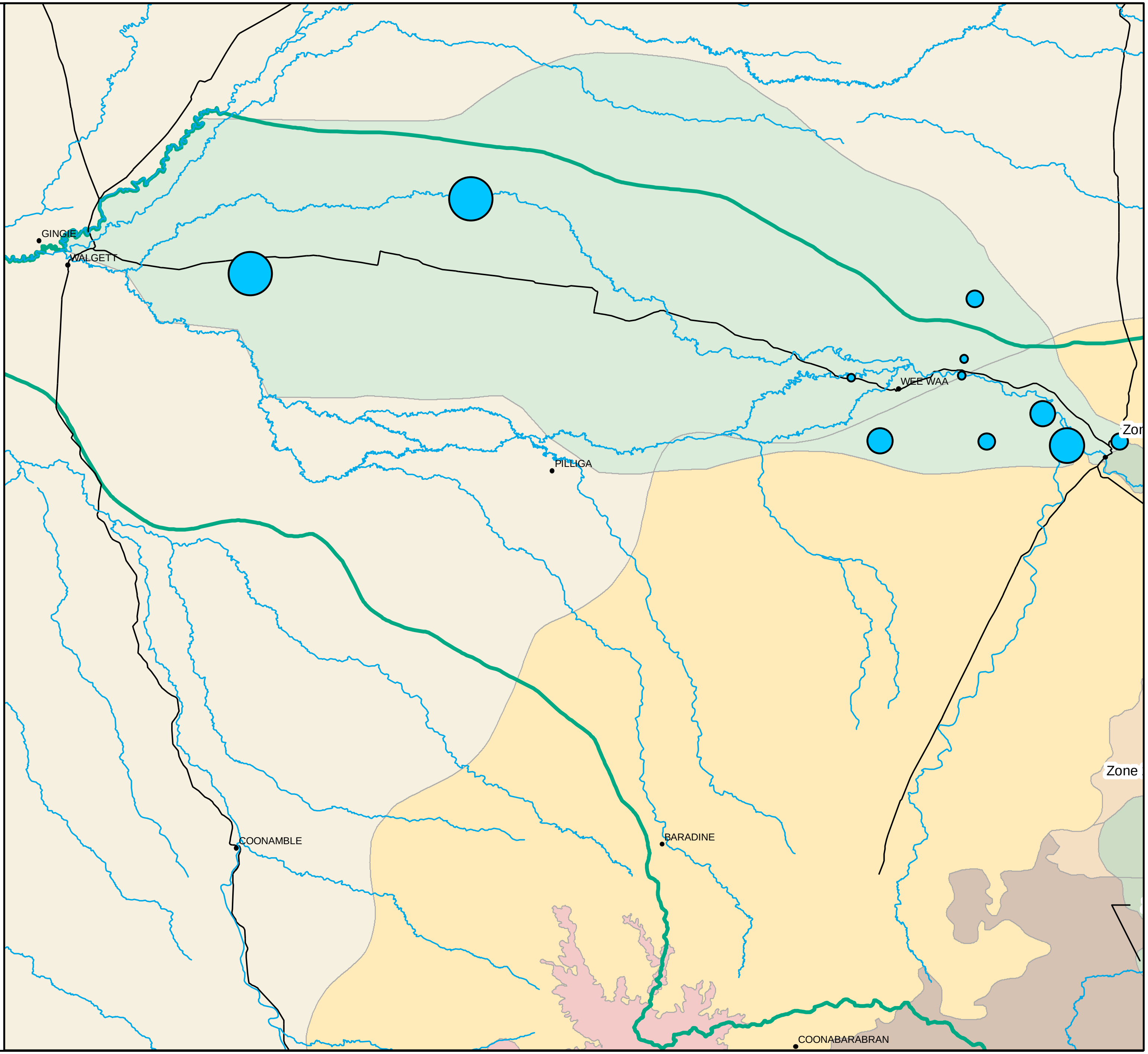


Figure A7.21

Namoi_6_1.mxd

WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 2

UPPER MONITORING UNIT, UPPER NAMOI

Figure

A7.22

Namoi_6_2.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

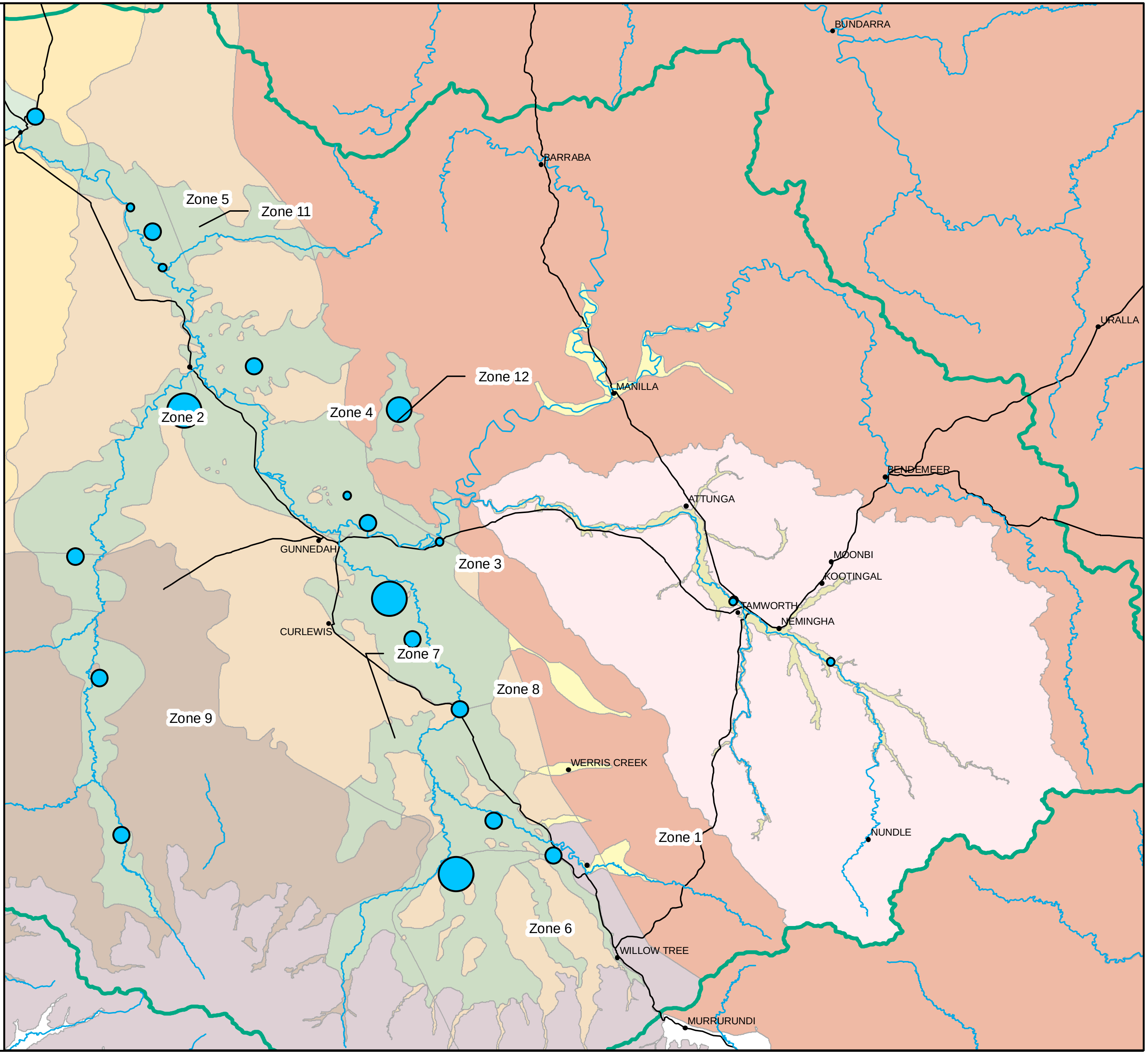
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL
Report No. 2009/25

SALINITY - WRL MONITORING ROUND 2
UPPER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure
A7.23

Namoi_6_2.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

Legend

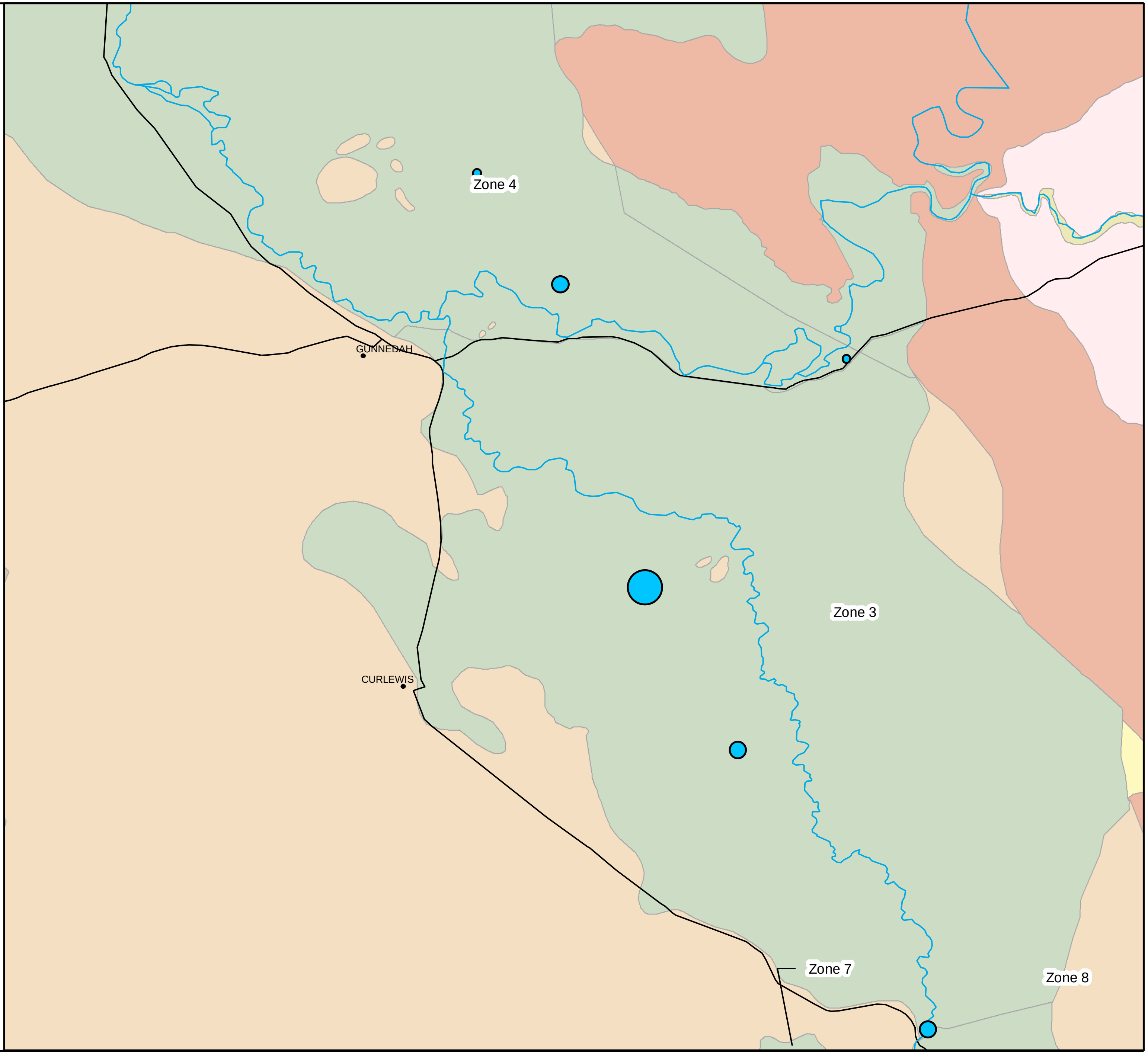
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 2
UPPER MONITORING UNIT, LOWER NAMOI

Figure A7.24

Namoi_6_2.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

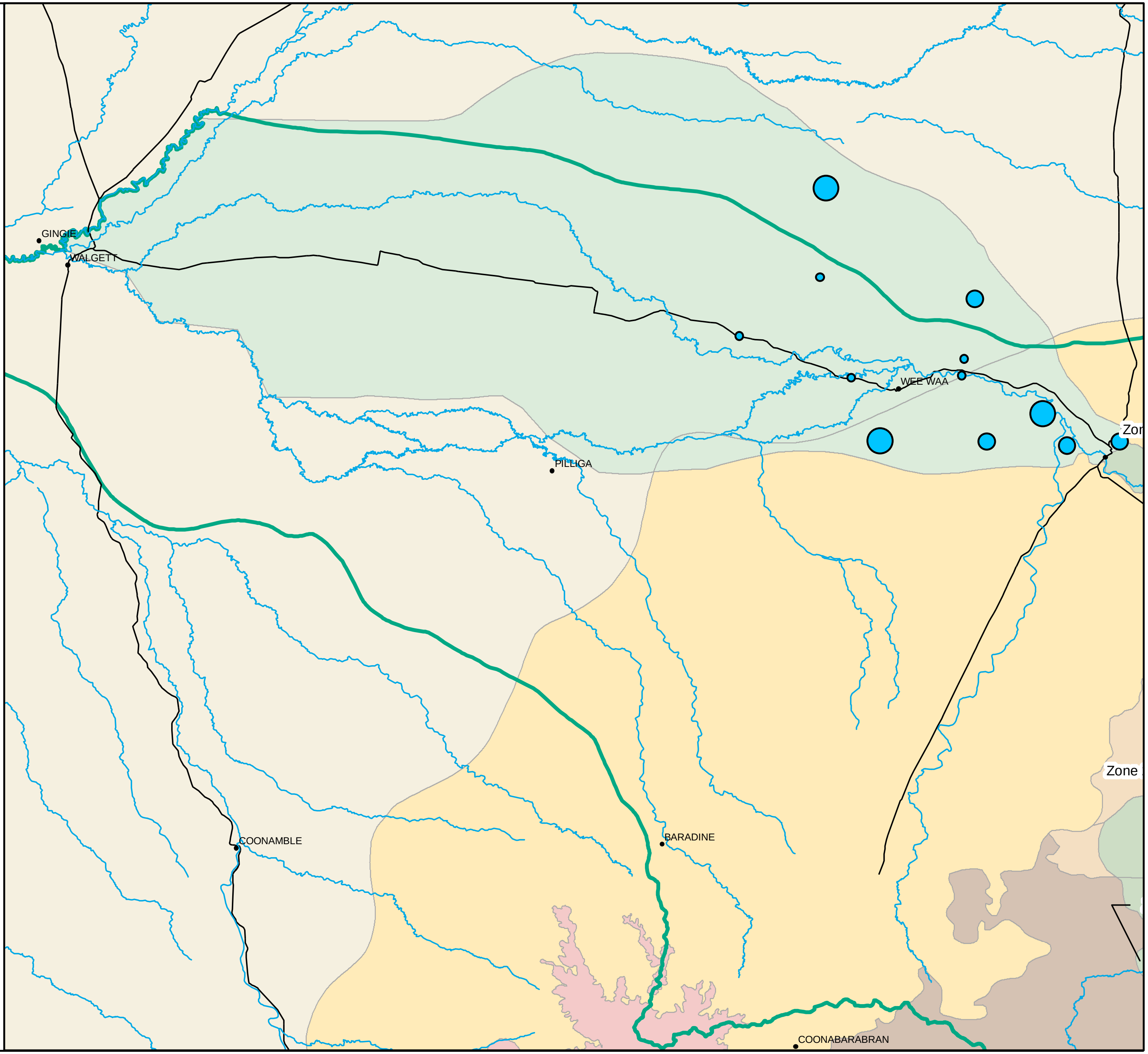
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL
Report No. 2009/25

2

0 5 10 20 Kilometres

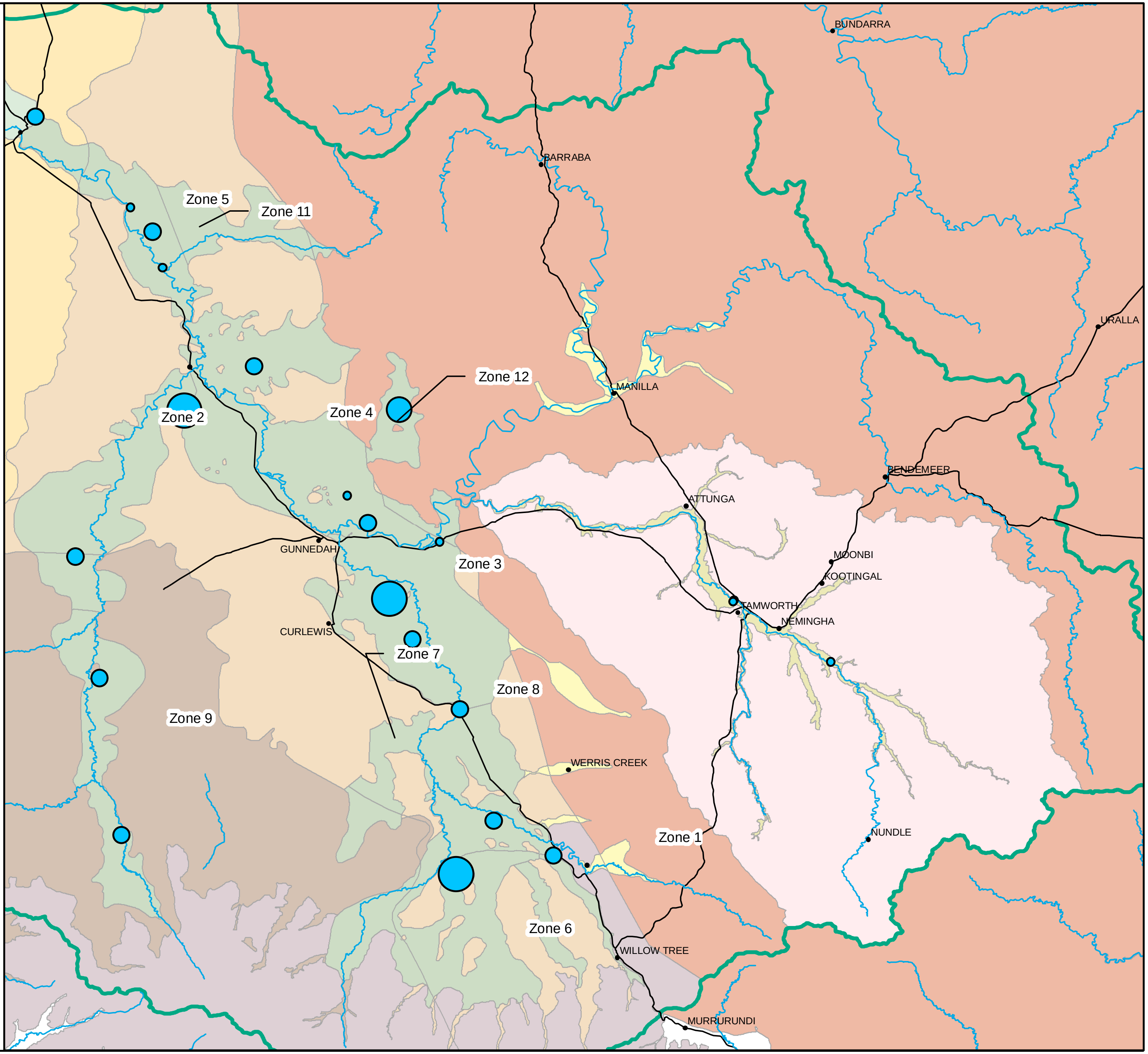
GDA94 (Lat/Long)

Legend

Electrical Conductivity (uS/cm)
- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA
- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



SALINITY - WRL MONITORING ROUND 3
UPPER MONITORING UNIT, UPPER NAMOI

Figure
A7.25

Namoi_6_3.mxd

WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 3
UPPER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure A7.26

Namoi_6_3.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

Legend

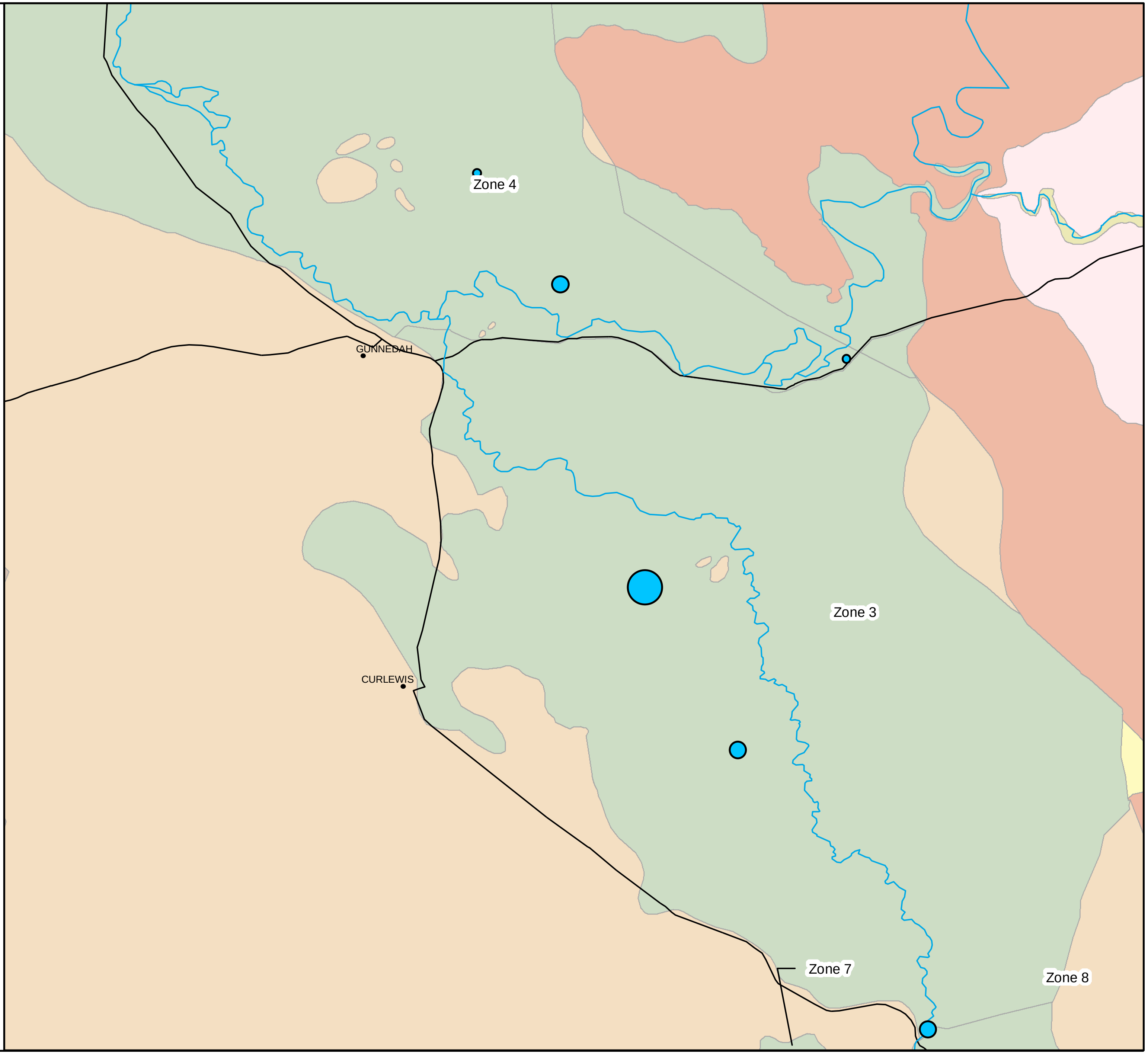
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

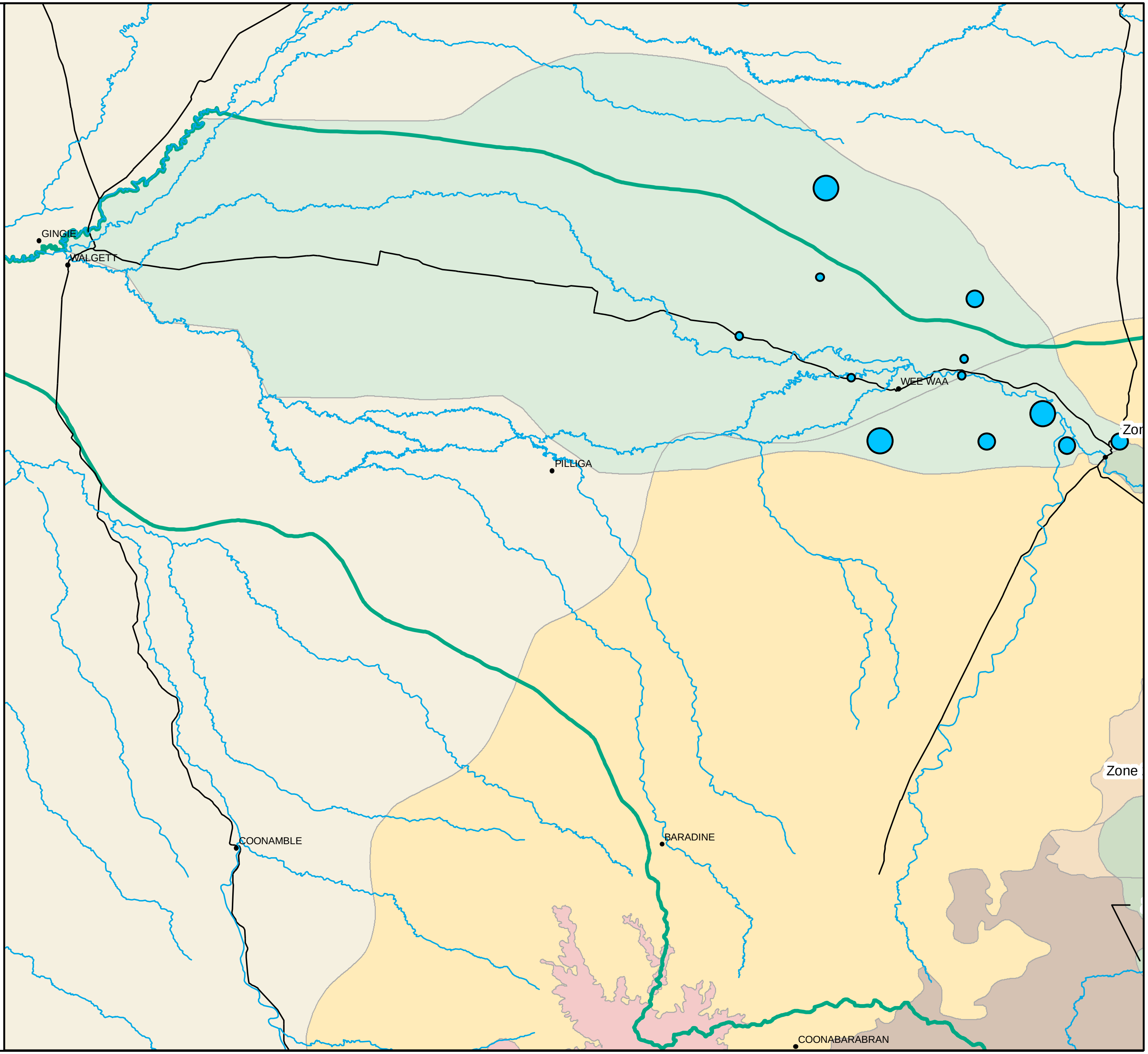
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



SALINITY - WRL MONITORING ROUND 3
UPPER MONITORING UNIT, LOWER NAMOI

Figure A7.27

Namoi_6_3.mxd

WRL
Report No. 2009/25

SALINITY - WRL MONITORING ROUND 1
LOWER MONITORING UNIT, UPPER NAMOI

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

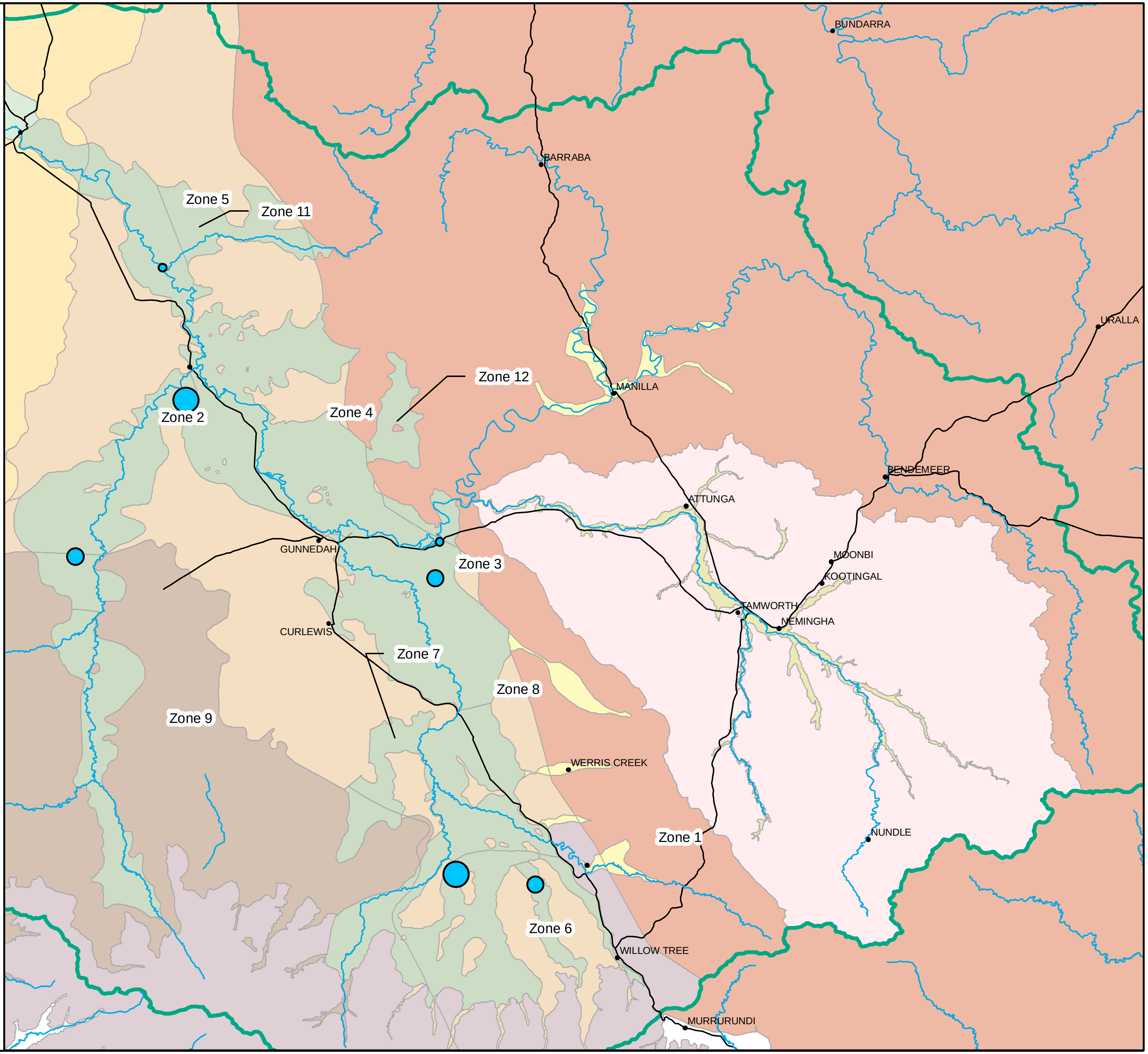


Figure
A7.28

Namoi_6_4.mxd

WRL
Report No. 2009/25

SALINITY - WRL MONITORING ROUND 1
LOWER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure
A7.29

Namoi_6_4.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

Legend

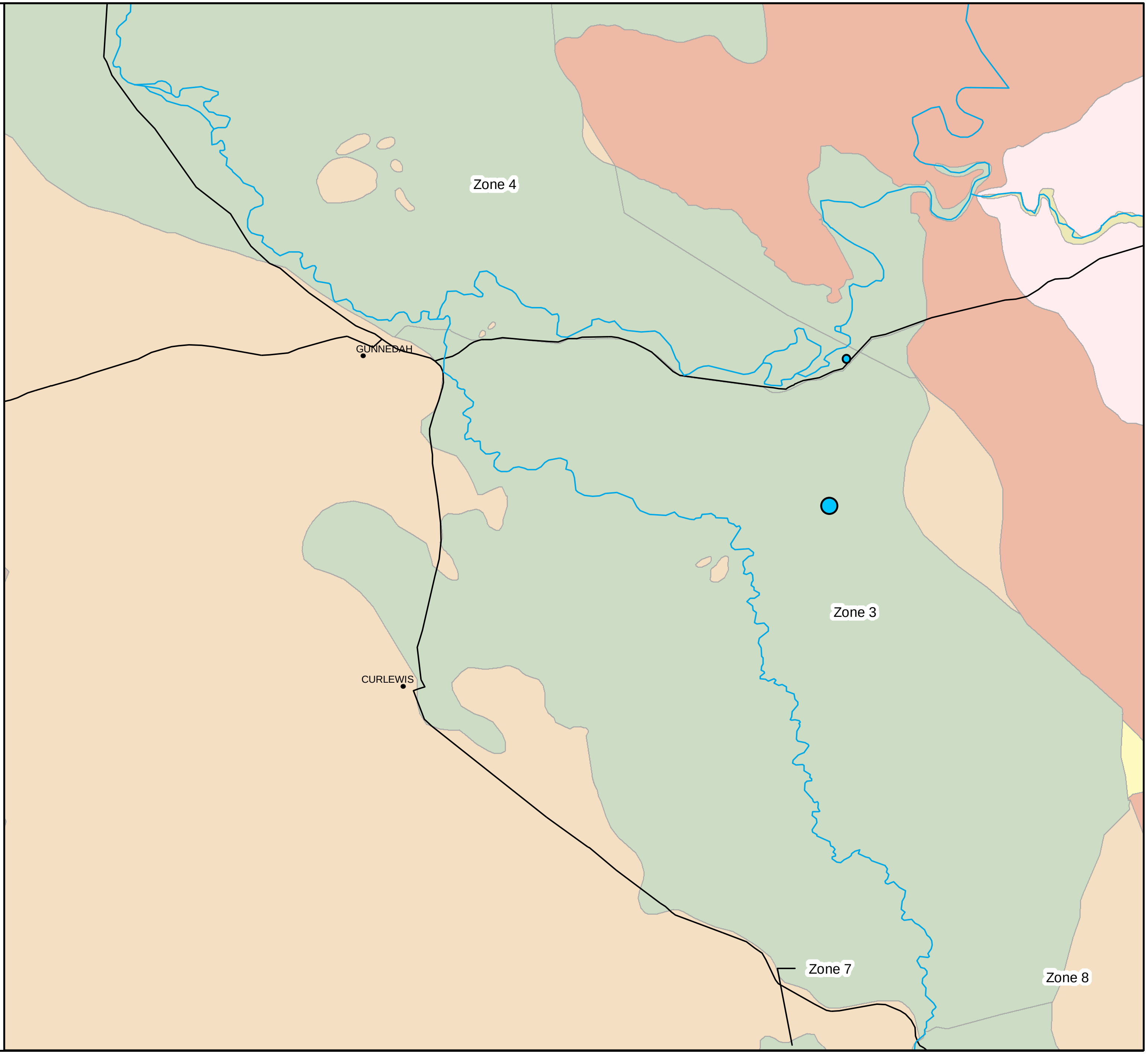
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 1
LOWER MONITORING UNIT, LOWER NAMOI

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

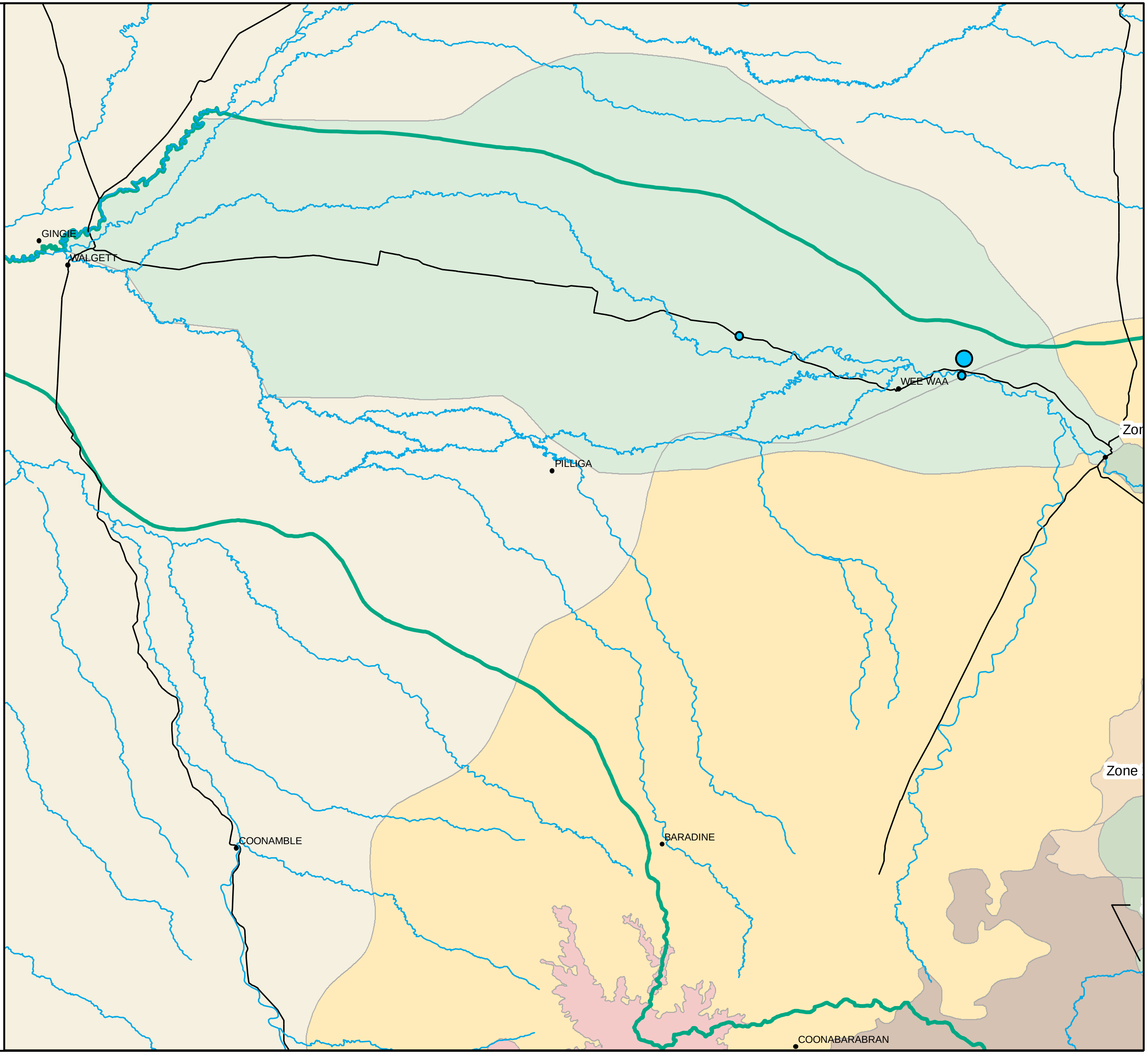


Figure A7.30

Namoi_6_4.mxd

WRL
Report No. 2009/25

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

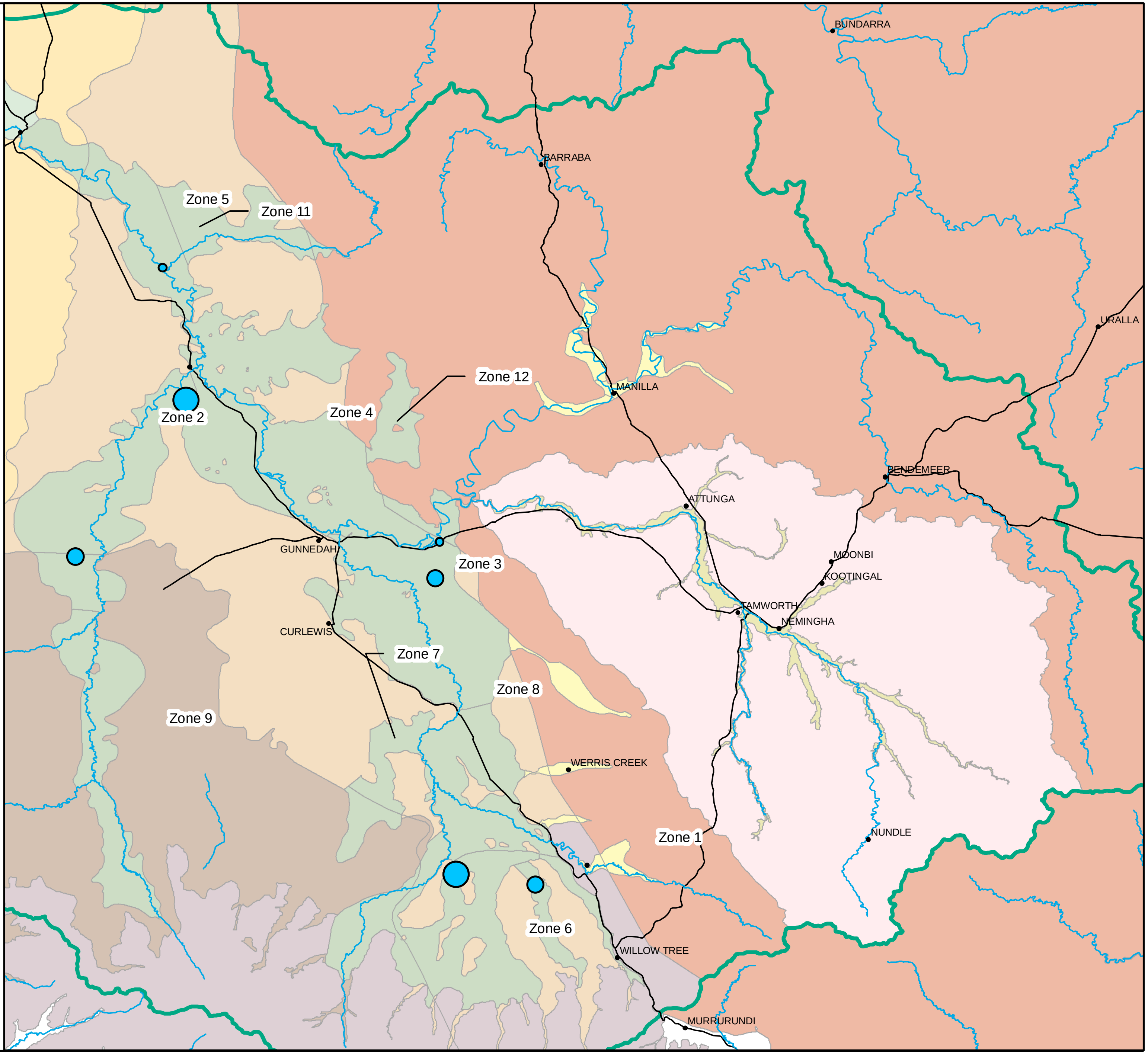
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



SALINITY - WRL MONITORING ROUND 2
LOWER MONITORING UNIT, UPPER NAMOI

Figure
A7.31

Namoi_6_5.mxd

WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 2

LOWER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure A7.32

Namoi_6_5.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

Legend

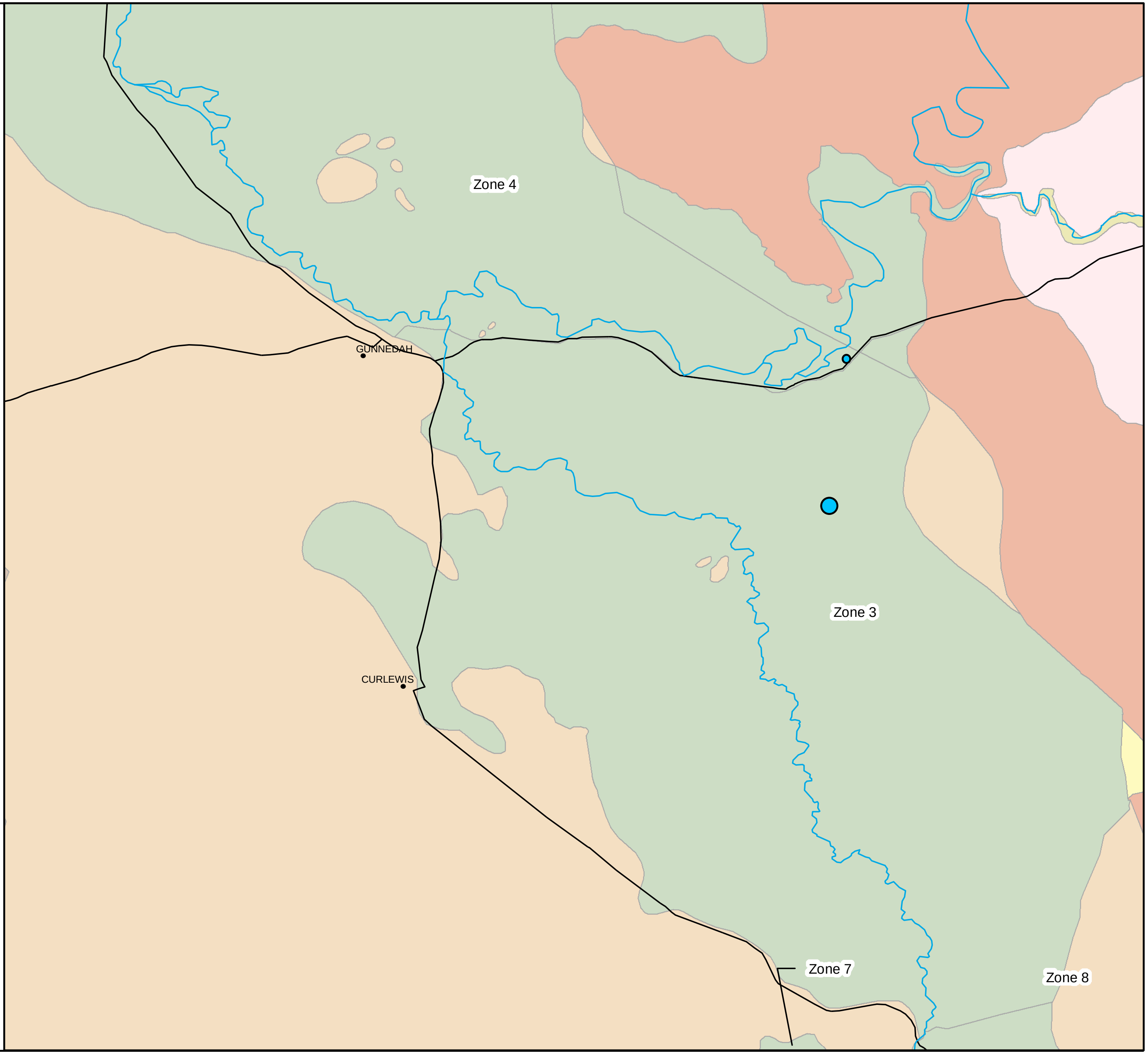
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

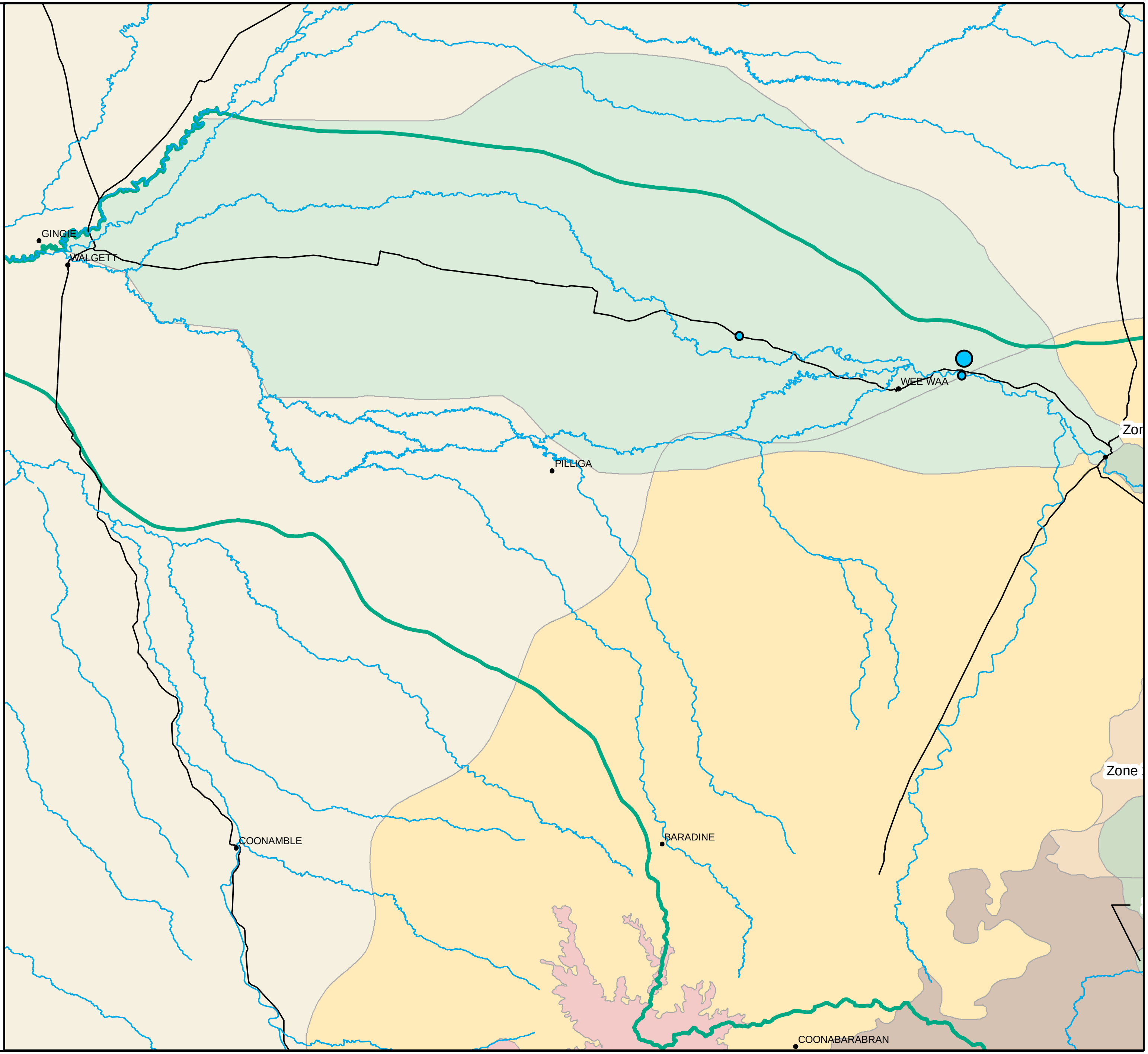
SALINITY - WRL MONITORING ROUND 2

LOWER MONITORING UNIT, LOWER NAMOI

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)



Legend

Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

Figure A7.33

Namoi_6_5.mxd

WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 3
LOWER MONITORING UNIT, UPPER NAMOI

Figure A7.34

Namoi_6_6.mxd

2

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

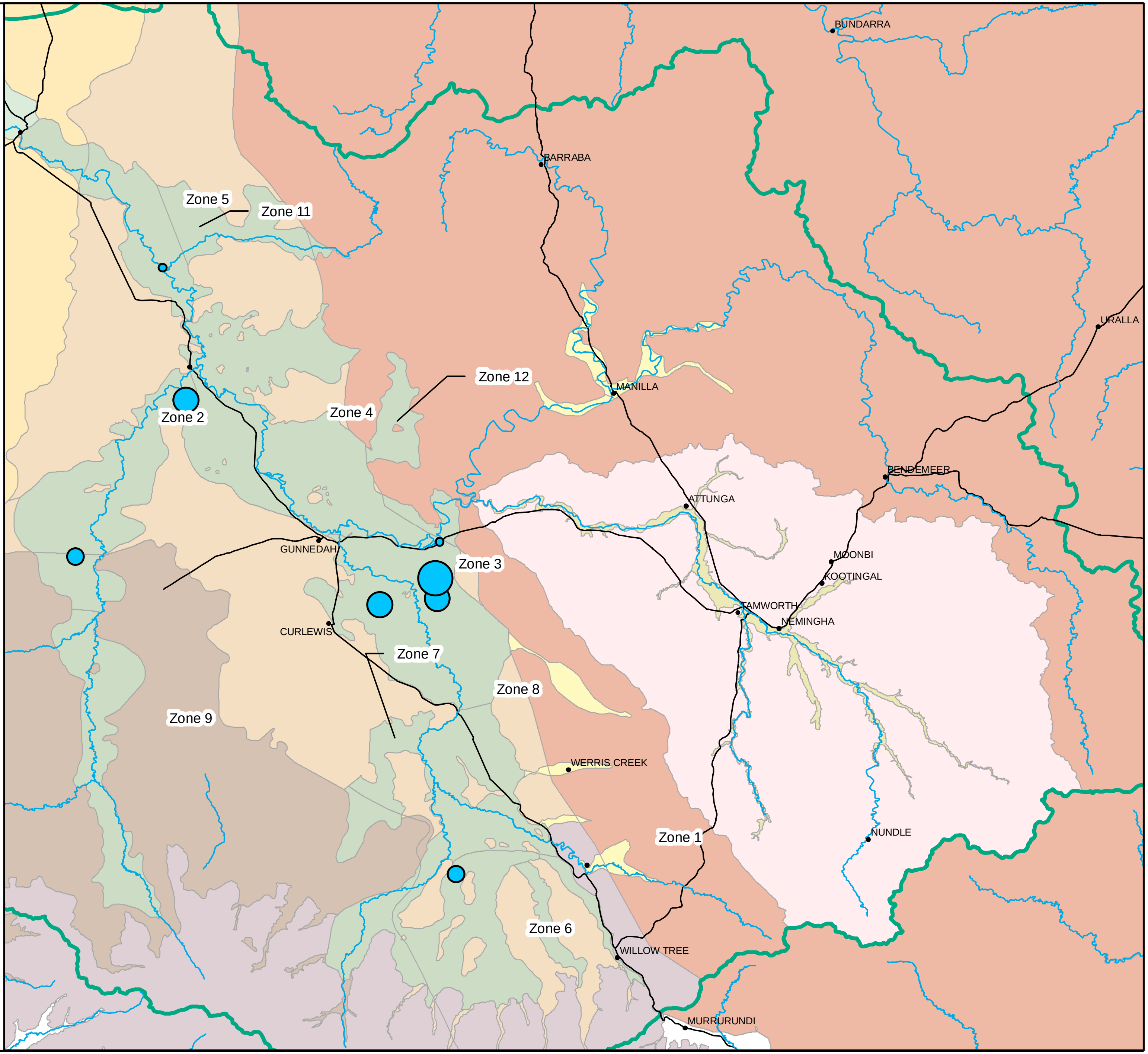
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

SALINITY - WRL MONITORING ROUND 3
LOWER MONITORING UNIT, UPPER NAMOI ZONE 3

Figure A7.35

Namoi_6_6.mxd

2

0 2 4 8 Kilometres

GDA94 (Lat/Long)

Legend

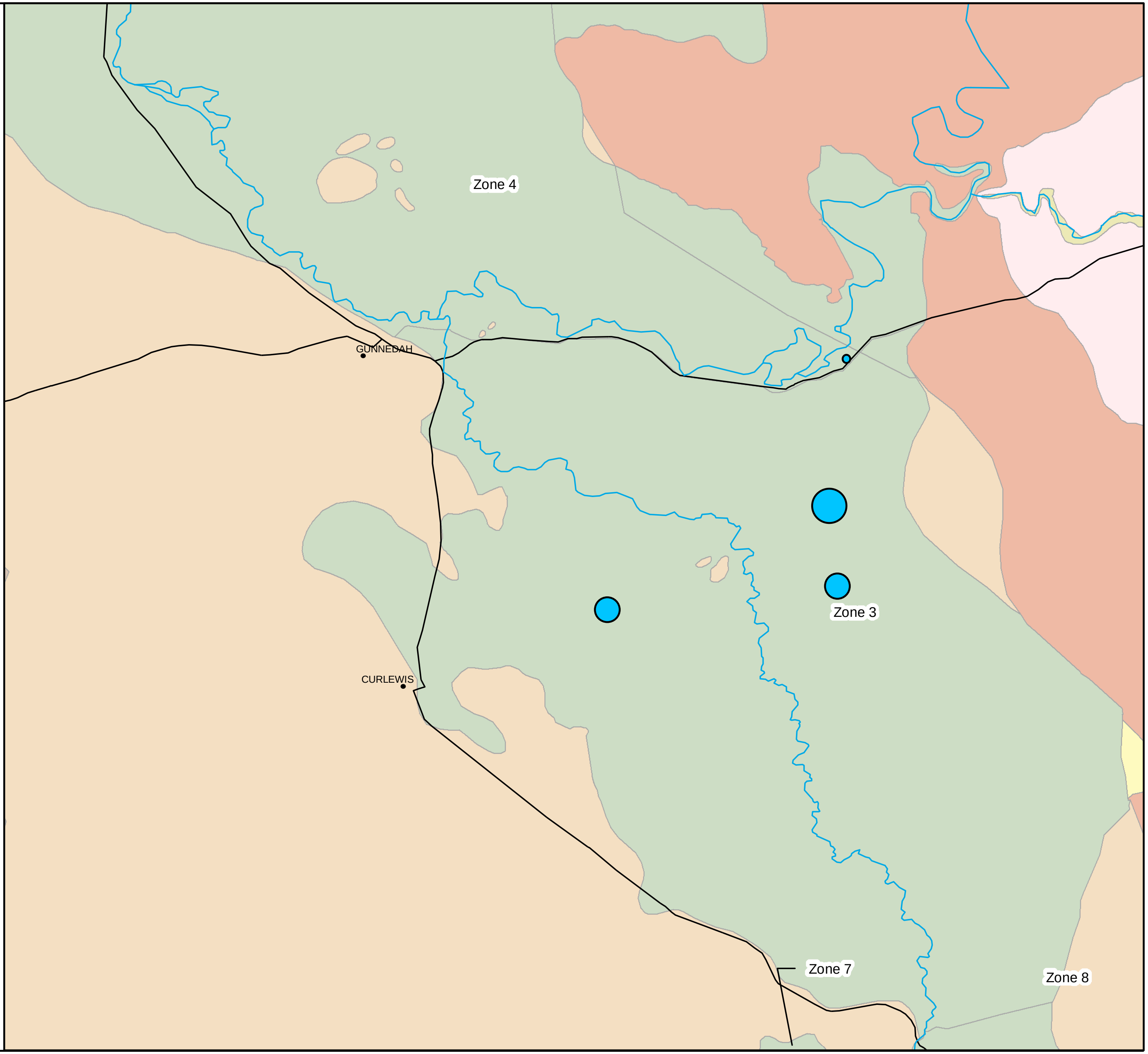
Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock



WRL

Report No. 2009/25

2

SALINITY - WRL MONITORING ROUND 3

LOWER MONITORING UNIT, LOWER NAMOI

0 5 10 20 Kilometres

GDA94 (Lat/Long)

Legend

Electrical Conductivity (uS/cm)

- <750
- 751 - 1500
- 1501 - 5000
- 5001 - 10000
- >10 000

- Towns
- Major Roads
- Major Rivers
- Catchment Area

GWMA

- 001 Lower Namoi Alluvium
- 004 Upper Namoi Alluvium
- 005 Peel Valley Alluvium
- 023 Mis. Alluvium of Barwon Region
- 063 GAB Alluvial
- 601 Great Artesian Basin
- 604 Gunnedah Basin
- 608 Oxley Basin
- 805 New England Fold Belt
- 813 Warrumbungle Tertiary Basalt
- 814 Liverpool Ranges Basalt
- 819 Peel Valley Fractured Rock

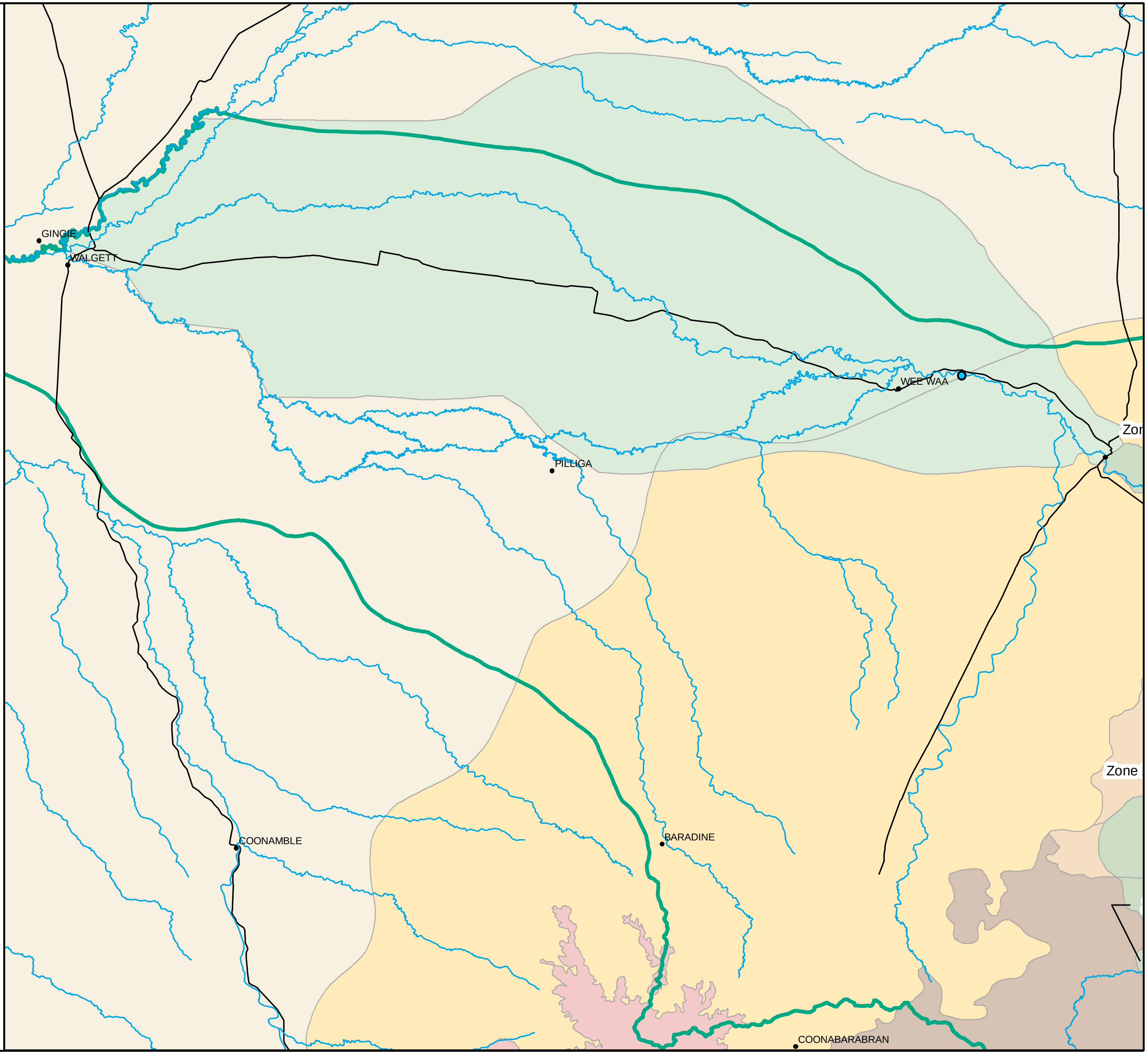


Figure A7.36

Namoi_6_6.mxd

APPENDIX A8
WATER QUALITY LABORATORY RESULTS (ALS)

CERTIFICATE OF ANALYSIS

Work Order	: **ES0901864**	Page	: 1 of 15
Amendment	: **1**		
Client	: **UNIVERSITY OF NSW**	Laboratory	: Environmental Division Sydney
Contact	: MS WENDY TIMMS	Contact	: Charlie Pierce
Address	: WATER RESEARCH LABORATORY KING STREET MANLY VALE NSW, AUSTRALIA 2093	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: w.timms@wrl.unsw.edu.au	E-mail	: charlie.pierce@alsenviro.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: WRL08085 NAMOI	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 10-FEB-2009
Sampler	: DR	Issue Date	: 23-APR-2009
Site	: ----		
		No. of samples received	: 60
Quote number	: SY/073/08	No. of samples analysed	: 60

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Celine Conceicao	Spectroscopist	Inorganics
Hoa Nguyen	Inorganic Chemist	Inorganics
Sarah Millington	Senior Inorganic Chemist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ED041: LOR raised for Turbidimetric Sulfate on sample ID 'GW036031-4' and 'GW036059-2' due to matrix interference.**
- **This report has been amended to allow the distribution of an Electronic Data Deliverable (EDD) not previously provided. All analysis results are as per the previous report.**

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036020-1	GW036029-1	GW036029-3	GW036042-1	GW036042-2
			Client sampling date / time	28-JAN-2009 15:00	28-JAN-2009 15:00	28-JAN-2009 15:00	28-JAN-2009 15:00	28-JAN-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-001	ES0901864-002	ES0901864-003	ES0901864-004	ES0901864-005
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	346	632	566	442	228
Total Alkalinity as CaCO3	----	1	mg/L	346	632	566	442	228
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	23	44	16	4	23
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	28	144	42	33	51
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	4	5	2	47	18
Magnesium	7439-95-4	1	mg/L	5	2	<1	31	17
Sodium	7440-23-5	1	mg/L	168	403	299	104	96
Potassium	7440-09-7	1	mg/L	3	1	2	6	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	8.17	17.6	12.8	9.86	6.48
^ Total Cations	----	0.01	meq/L	7.99	18.0	13.2	9.60	6.51
^ Ionic Balance	----	0.01	%	1.20	1.02	1.20	1.39	0.21

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036028-1	GW036020-2	GW036022-2	GW036012-1	GW036012-2
			Client sampling date / time	28-JAN-2009 15:00	29-JAN-2009 15:00	29-JAN-2009 15:00	29-JAN-2009 15:00	29-JAN-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-006	ES0901864-007	ES0901864-008	ES0901864-009	ES0901864-010
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	188	434	130	601	678
Total Alkalinity as CaCO3	----	1	mg/L	188	434	130	601	678
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	39	26	12	27	70
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	49	61	13	85	472
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	32	5	20	4	17
Magnesium	7439-95-4	1	mg/L	21	4	10	4	10
Sodium	7440-23-5	1	mg/L	54	238	31	329	610
Potassium	7440-09-7	1	mg/L	2	4	2	6	7
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	----	10.9	3.23	15.0	28.3
Total Anions	----	0.01	meq/L	5.95	----	----	----	----
^ Total Cations	----	0.01	meq/L	5.75	11.0	3.26	15.0	28.4
^ Ionic Balance	----	0.01	%	----	0.39	0.50	0.09	0.06
Ionic Balance	----	0.01	%	1.96	----	----	----	----

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036028-4	GW036021-2	GW036031-1	GW036031-2	GW036094-1
			Client sampling date / time	29-JAN-2009 15:00	30-JAN-2009 15:00	30-JAN-2009 15:00	30-JAN-2009 15:00	30-JAN-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-011	ES0901864-012	ES0901864-013	ES0901864-014	ES0901864-015
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	424	392	230	201	213
Total Alkalinity as CaCO3	----	1	mg/L	424	392	230	201	213
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	2	14	10	22	40
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	29	69	33	20	51
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	25	18	34	30	35
Magnesium	7439-95-4	1	mg/L	10	10	12	10	18
Sodium	7440-23-5	1	mg/L	159	183	64	59	69
Potassium	7440-09-7	1	mg/L	3	1	3	2	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	9.34	10.1	----	5.03	6.52
Total Anions	----	0.01	meq/L	----	----	5.74	----	----
^ Total Cations	----	0.01	meq/L	9.08	9.73	5.54	4.97	6.33
^ Ionic Balance	----	0.01	%	1.40	1.73	----	0.60	1.45
Ionic Balance	----	0.01	%	----	----	1.72	----	----

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036094-3	GW036096-1	GW036096-2	GW036041-1	GW036041-2
			Client sampling date / time	30-JAN-2009 15:00	30-JAN-2009 15:00	30-JAN-2009 15:00	31-JAN-2009 15:00	31-JAN-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-016	ES0901864-017	ES0901864-018	ES0901864-019	ES0901864-020
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	276	172	205	298	360
Total Alkalinity as CaCO3	----	1	mg/L	276	172	205	298	360
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	42	21	39	1620	103
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	51	38	59	4900	600
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	26	33	57	259	16
Magnesium	7439-95-4	1	mg/L	8	12	28	285	12
Sodium	7440-23-5	1	mg/L	131	56	26	3110	586
Potassium	7440-09-7	1	mg/L	2	2	2	6	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	7.82	4.96	----	----	----
Total Anions	----	0.01	meq/L	----	----	6.58	178	26.3
^ Total Cations	----	0.01	meq/L	7.72	5.09	6.38	172	27.3
^ Ionic Balance	----	0.01	%	0.69	1.35	----	----	----
Ionic Balance	----	0.01	%	----	----	1.90	1.72	1.97

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	GW036014-1	GW036014-3	GW036031-2	GW036031-4	GW036059-1
			Client sampling date / time	31-JAN-2009 15:00	31-JAN-2009 15:00	01-FEB-2009 15:00	01-FEB-2009 15:00	01-FEB-2009 15:00
Compound	*CAS Number*	*LOR*	*Unit*	ES0901864-021	ES0901864-022	ES0901864-023	ES0901864-024	ES0901864-025
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	429	252	126	120	1650
Total Alkalinity as CaCO3	----	1	mg/L	429	252	126	120	1650
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	3400	148	25	<10	374
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	9480	1180	26	6	1180
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	685	44	23	17	18
Magnesium	7439-95-4	1	mg/L	883	47	12	8	39
Sodium	7440-23-5	1	mg/L	6110	815	32	20	1610
Potassium	7440-09-7	1	mg/L	7	2	4	4	16
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	347	41.4	3.77	2.56	74.0
^ Total Cations	----	0.01	meq/L	373	41.6	3.65	2.52	74.7
^ Ionic Balance	----	0.01	%	3.61	0.20	1.60	----	0.43

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036059-2	GW036052-1	GW036052-3	GW036600-3	GW036602-1
			Client sampling date / time	01-FEB-2009 15:00	01-FEB-2009 15:00	01-FEB-2009 15:00	01-FEB-2009 15:00	02-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-026	ES0901864-027	ES0901864-028	ES0901864-029	ES0901864-030
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	31	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	612	395	355	791	402
Total Alkalinity as CaCO3	----	1	mg/L	643	395	355	791	402
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<5	38	26	55	140
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	49	76	60	820	787
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	5	56	39	75	39
Magnesium	7439-95-4	1	mg/L	1	18	16	90	56
Sodium	7440-23-5	1	mg/L	325	136	131	652	622
Potassium	7440-09-7	1	mg/L	3	1	1	10	3
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	14.2	10.8	9.33	40.1	33.2
^ Total Cations	----	0.01	meq/L	14.6	10.2	9.03	39.8	33.7
^ Ionic Balance	----	0.01	%	1.15	3.19	1.67	0.41	0.80

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036602-2	GW036415-1	GW036415-3	GW030344-1	GW030344-3
			Client sampling date / time	02-FEB-2009 15:00	02-FEB-2009 15:00	03-FEB-2009 15:00	03-FEB-2009 15:00	03-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-031	ES0901864-032	ES0901864-033	ES0901864-034	ES0901864-035
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	662	463	249	185	266
Total Alkalinity as CaCO3	----	1	mg/L	662	463	249	185	266
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	358	240	41	30	16
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	1480	69	50	48	10
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	58	139	55	48	31
Magnesium	7439-95-4	1	mg/L	121	56	18	23	18
Sodium	7440-23-5	1	mg/L	1140	92	68	27	62
Potassium	7440-09-7	1	mg/L	8	1	1	<1	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	62.5	----	7.24	5.68	5.94
Total Anions	----	0.01	meq/L	----	16.2	----	----	----
^ Total Cations	----	0.01	meq/L	62.7	15.6	7.24	5.43	5.78
^ Ionic Balance	----	0.01	%	0.12	----	<0.01	----	1.44
Ionic Balance	----	0.01	%	----	1.99	----	1.94	----

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036238-1	GW036238-3	GW030306-1	GW030306-2	GW036515-1
			Client sampling date / time	03-FEB-2009 15:00	03-FEB-2009 15:00	03-FEB-2009 15:00	04-FEB-2009 15:00	04-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-036	ES0901864-037	ES0901864-038	ES0901864-039	ES0901864-040
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	222	176	183	173	489
Total Alkalinity as CaCO3	----	1	mg/L	222	176	183	173	489
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	81	11	37	41	22
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	50	7	48	39	115
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	59	16	42	46	11
Magnesium	7439-95-4	1	mg/L	29	10	22	23	17
Sodium	7440-23-5	1	mg/L	57	49	37	29	265
Potassium	7440-09-7	1	mg/L	1	2	2	2	<1
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	7.54	3.94	----	5.43	13.5
Total Anions	----	0.01	meq/L	----	----	5.78	----	----
^ Total Cations	----	0.01	meq/L	7.84	3.85	5.62	5.53	13.5
^ Ionic Balance	----	0.01	%	1.91	1.23	----	0.95	0.12
Ionic Balance	----	0.01	%	----	----	1.92	----	----

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036515-3	GW036566-1	GW036654-1	GW036654-2	GW030000-1
			Client sampling date / time	04-FEB-2009 15:00	04-FEB-2009 15:00	04-FEB-2009 15:00	04-FEB-2009 15:00	05-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-041	ES0901864-042	ES0901864-043	ES0901864-044	ES0901864-045
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	449	401	322	296	310
Total Alkalinity as CaCO3	----	1	mg/L	449	401	322	296	310
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	2	10	2	2	32
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	49	214	63	50	101
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	31	53	38	36	46
Magnesium	7439-95-4	1	mg/L	32	60	48	41	34
Sodium	7440-23-5	1	mg/L	127	121	49	43	96
Potassium	7440-09-7	1	mg/L	4	3	2	2	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	----	----	8.24	7.37	----
Total Anions	----	0.01	meq/L	10.4	14.3	----	----	9.67
^ Total Cations	----	0.01	meq/L	9.81	12.9	8.03	7.08	9.34
^ Ionic Balance	----	0.01	%	----	----	1.31	----	----
Ionic Balance	----	0.01	%	2.95	4.94	----	1.94	1.86

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036166-1	GW036210-1	GW036210-3	GW030430-2	GW030430-4
			Client sampling date / time	05-FEB-2009 15:00	05-FEB-2009 15:00	05-FEB-2009 15:00	05-FEB-2009 15:00	05-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-046	ES0901864-047	ES0901864-048	ES0901864-049	ES0901864-050
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	481	921	856	301	319
Total Alkalinity as CaCO3	----	1	mg/L	481	921	856	301	319
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	4170	274	44	25	15
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	1800	1100	139	74	40
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	302	372	184	21	23
Magnesium	7439-95-4	1	mg/L	332	129	49	16	13
Sodium	7440-23-5	1	mg/L	2500	558	161	144	121
Potassium	7440-09-7	1	mg/L	4	3	4	1	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	147	55.1	22.0	8.62	7.81
^ Total Cations	----	0.01	meq/L	151	53.6	20.3	8.67	7.55
^ Ionic Balance	----	0.01	%	1.21	1.43	3.89	0.25	1.72

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW030140-1	GW030136-1	GW030168-1	GW030168-2	GW030059-1
			Client sampling date / time	06-FEB-2009 15:00	06-FEB-2009 15:00	06-FEB-2009 15:00	06-FEB-2009 15:00	07-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-051	ES0901864-052	ES0901864-053	ES0901864-054	ES0901864-055
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	194	212	156	147	246
Total Alkalinity as CaCO3	----	1	mg/L	194	212	156	147	246
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	34	49	19	15	6
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	20	39	8	9	99
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	38	57	28	28	17
Magnesium	7439-95-4	1	mg/L	21	24	18	16	18
Sodium	7440-23-5	1	mg/L	31	29	19	14	115
Potassium	7440-09-7	1	mg/L	<1	<1	<1	2	8
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	5.16	6.35	3.74	3.51	7.84
^ Total Cations	----	0.01	meq/L	4.97	6.08	3.72	3.45	7.58
^ Ionic Balance	----	0.01	%	1.80	----	0.34	0.86	1.72
Ionic Balance	----	0.01	%	----	1.92	----	----	----

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW030061-1	GW040882-1	GW040882-4	GW030184-1	GW030184-2
			Client sampling date / time	07-FEB-2009 15:00	07-FEB-2009 15:00	07-FEB-2009 15:00	07-FEB-2009 15:00	07-FEB-2009 15:00
Compound	CAS Number	LOR	Unit	ES0901864-056	ES0901864-057	ES0901864-058	ES0901864-059	ES0901864-060
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	8	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	314	246	385	315	336
Total Alkalinity as CaCO3	----	1	mg/L	322	246	385	315	336
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	28	462	3	38	42
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	275	2760	286	106	111
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	11	108	15	81	86
Magnesium	7439-95-4	1	mg/L	19	273	19	45	48
Sodium	7440-23-5	1	mg/L	283	1550	292	62	62
Potassium	7440-09-7	1	mg/L	4	4	6	2	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	14.8	92.5	15.8	10.1	10.7
^ Total Cations	----	0.01	meq/L	14.5	95.5	15.1	10.5	11.0
^ Ionic Balance	----	0.01	%	0.85	1.58	2.29	1.92	1.18

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **ES0905268**	Page	: 1 of 7
Amendment	: **1**		
Client	: **UNIVERSITY OF NSW**	Laboratory	: Environmental Division Sydney
Contact	: DUNCAN RAYNER	Contact	: Charlie Pierce
Address	: WATER RESEARCH LABORATORY KING STREET MANLY VALE NSW, AUSTRALIA 2093	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: d.rayner@wrl.unsw.edu.au	E-mail	: charlie.pierce@alsenviro.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: WRL08085 NAMOI	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 09-APR-2009
Sampler	: ----	Issue Date	: 22-APR-2009
Site	: ----		
		No. of samples received	: 20
Quote number	: SY/073/08	No. of samples analysed	: 19

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Celine Conceicao	Spectroscopist	Inorganics
Hoa Nguyen	Inorganic Chemist	Inorganics
Sarah Millington	Senior Inorganic Chemist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **LCS recovery for Magnesium falls outside ALS Dynamic Control Limit. However, it is within the acceptance criteria based on ALS DQO. No further action is required.**
- **This report has been amended to allow the distribution of an Electronic Data Deliverable (EDD) not previously provided. All analysis results are as per the previous report.**

Analytical Results

Sub-Matrix: WATER			Client sample ID	SURFACE # 01	SURFACE # 02	SURFACE # 03	SURFACE # 04	SURFACE # 05
			Client sampling date / time	31-MAR-2009 10:10	30-MAR-2009 17:00	02-APR-2009 13:00	03-APR-2009 09:10	03-APR-2009 11:45
Compound	*CAS Number*	*LOR*	*Unit*	ES0905268-001	ES0905268-002	ES0905268-003	ES0905268-004	ES0905268-005
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	12	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	128	132	370	213	163
Total Alkalinity as CaCO3	----	1	mg/L	128	132	382	213	163
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	7	26	2	30	8
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	18	38	75	55	11
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	24	31	38	48	28
Magnesium	7439-95-4	1	mg/L	13	18	59	30	19
Sodium	7440-23-5	1	mg/L	20	25	68	33	18
Potassium	7440-09-7	1	mg/L	4	5	3	2	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	3.20	4.26	9.81	6.42	3.73
^ Total Cations	----	0.01	meq/L	3.27	4.28	9.81	6.41	3.79
^ Ionic Balance	----	0.01	%	1.17	0.20	<0.01	0.05	0.84

Analytical Results

Sub-Matrix: WATER			Client sample ID	SURFACE # 06	SURFACE # 07	GW036140-1	GW036541-1	GW036140-3
			Client sampling date / time	04-APR-2009 11:35	04-APR-2009 15:40	30-MAR-2009 14:55	30-MAR-2009 13:00	30-MAR-2009 15:50
Compound	CAS Number	LOR	Unit	ES0905268-006	ES0905268-007	ES0905268-008	ES0905268-009	ES0905268-010
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	----	----	492	16200	499
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	33	14	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	263	277	220	315	231
Total Alkalinity as CaCO3	----	1	mg/L	296	291	220	315	231
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	<1	10	1140	6
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	98	84	31	4930	21
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	40	40	26	269	24
Magnesium	7439-95-4	1	mg/L	50	42	14	332	12
Sodium	7440-23-5	1	mg/L	58	58	65	3310	70
Potassium	7440-09-7	1	mg/L	6	6	1	6	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	8.68	8.20	5.47	169	5.34
^ Total Cations	----	0.01	meq/L	8.78	8.13	5.36	185	5.25
^ Ionic Balance	----	0.01	%	0.53	0.45	1.05	4.43	0.82

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	GW036166-1	GW030063-3	GW030063-2	GW036140-2	GW025299-1
			Client sampling date / time	04-APR-2009 16:35	05-APR-2009 15:30	05-APR-2009 15:30	30-MAR-2009 15:25	30-MAR-2009 17:20
				ES0905268-011	ES0905268-012	ES0905268-013	ES0905268-014	ES0905268-015
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	14200	1030	1000	499	2720
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	468	296	316	230	318
Total Alkalinity as CaCO3	----	1	mg/L	468	296	316	230	318
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	5490	56	68	7	144
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	1460	115	110	22	676
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	428	78	71	24	81
Magnesium	7439-95-4	1	mg/L	466	56	54	12	61
Sodium	7440-23-5	1	mg/L	2780	52	50	68	471
Potassium	7440-09-7	1	mg/L	3	2	2	2	3
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	165	10.3	10.8	5.35	28.4
^ Total Cations	----	0.01	meq/L	181	10.9	10.2	5.18	29.6
^ Ionic Balance	----	0.01	%	4.52	2.57	2.86	1.61	2.02

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036314-1	GW025146-3	GW037014-1	GW037014-3	----
			Client sampling date / time	30-MAR-2009 12:35	30-MAR-2009 16:30	31-MAR-2009 16:40	31-MAR-2009 17:00	----
Compound	CAS Number	LOR	Unit	ES0905268-016	ES0905268-017	ES0905268-018	ES0905268-019	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	28500	360	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	418	162	<1	<1	----
Total Alkalinity as CaCO3	----	1	mg/L	418	162	<1	<1	----
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	2640	10	<1	<1	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	10400	11	<1	3	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	595	16	<1	<1	----
Magnesium	7439-95-4	1	mg/L	945	9	<1	<1	----
Sodium	7440-23-5	1	mg/L	6110	50	<1	2	----
Potassium	7440-09-7	1	mg/L	7	1	<1	<1	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	356	3.78	<0.01	0.07	----
^ Total Cations	----	0.01	meq/L	373	3.71	<0.01	0.09	----
^ Ionic Balance	----	0.01	%	2.35	0.88	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **ES0905709**	Page	: 1 of 4
Amendment	: **1**		
Client	: **UNIVERSITY OF NSW**	Laboratory	: Environmental Division Sydney
Contact	: DUNCAN RAYNER	Contact	: Charlie Pierce
Address	: WATER RESEARCH LABORATORY KING STREET MANLY VALE NSW, AUSTRALIA 2093	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: d.rayner@wrl.unsw.edu.au	E-mail	: charlie.pierce@alsenviro.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: WRL08085 NAMOI REBATCH OF ES0905268	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: REBATCH OF ES0905268		
C-O-C number	: ----	Date Samples Received	: 21-APR-2009
Sampler	: DR	Issue Date	: 29-APR-2009
Site	: ----		
		No. of samples received	: 1
Quote number	: SY/187/09	No. of samples analysed	: 1

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Celine Conceicao	Spectroscopist	Inorganics
Sarah Millington	Senior Inorganic Chemist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	GW030063-1	----	----	----	----
			Client sampling date / time	05-APR-2009 16:05	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	ES0905709-001	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1020**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**317**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**317**	----	----	----	----
ED041: Sulfate (Turbidimetric) as SO4 2-								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**65**	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**109**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**82**	----	----	----	----
Magnesium	7439-95-4	1	mg/L	**50**	----	----	----	----
Sodium	7440-23-5	1	mg/L	**52**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**2**	----	----	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**10.8**	----	----	----	----
^ Total Cations	----	0.01	meq/L	**10.6**	----	----	----	----
^ Ionic Balance	----	0.01	%	**0.80**	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **ES0911547**	Page	: 1 of 8
Client	: **UNIVERSITY OF NSW**	Laboratory	: Environmental Division Sydney
Contact	: MS WENDY TIMMS	Contact	: Charlie Pierce
Address	: WATER RESEARCH LABORATORY KING STREET MANLY VALE NSW, AUSTRALIA 2093	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: w.timms@wrl.unsw.edu.au	E-mail	: charlie.pierce@alsenviro.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: WRL08085 NAMOI	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 05-AUG-2009
Sampler	: DR	Issue Date	: 13-AUG-2009
Site	: ----		
		No. of samples received	: 28
Quote number	: SY/187/09	No. of samples analysed	: 28

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA

WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Phyu Phyu Lwin	Inorganic Chemist	Inorganics
Sarah Millington	Senior Inorganic Chemist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ED009: LCS recovery for Sulfate falls outside ALS dynamic control limits. However, it is within the acceptance criteria based on ALS DQO. No further action is required.**
- **EN055-IC: Ionic Balance out of acceptable limits for sample ID 'SURFACE 1' due to analytes not quantified in this report.**

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW025299-1	GW025299-2	GW025321-2	GW025331-2	GW025331-3
			Client sampling date / time	22-JUL-2009 16:00	22-JUL-2009 16:30	22-JUL-2009 09:00	22-JUL-2009 15:00	22-JUL-2009 11:10
Compound	*CAS Number*	*LOR*	*Unit*	ES0911547-001	ES0911547-002	ES0911547-003	ES0911547-004	ES0911547-005
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	1200	1060	66.9	28.9	27.4
Sulfate	14808-79-8	0.20	mg/L	332	292	10.8	30.9	21.2
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	291	277	379	127	163
Total Alkalinity as CaCO3	----	1	mg/L	291	277	379	127	163
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	162	146	19	25	36
Magnesium	7439-95-4	1	mg/L	111	99	10	14	20
Sodium	7440-23-5	1	mg/L	699	630	177	32	20
Potassium	7440-09-7	1	mg/L	4	4	1	2	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	46.5	41.4	9.69	3.99	4.48
^ Total Cations	----	0.01	meq/L	47.7	43.0	9.54	3.90	4.41
^ Ionic Balance	----	0.01	%	1.28	1.86	0.80	1.12	0.70

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW025331-4	GW030052-1	GW030052-2	GW036096-1	GW036096-2
			Client sampling date / time	22-JUL-2009 10:35	25-JUL-2009 13:35	25-JUL-2009 14:05	24-JUL-2009 11:55	24-JUL-2009 12:15
Compound	CAS Number	LOR	Unit	ES0911547-006	ES0911547-007	ES0911547-008	ES0911547-009	ES0911547-010
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	12.5	80.5	78.4	50.4	63.1
Sulfate	14808-79-8	0.20	mg/L	1.92	28.4	24.2	38.5	35.9
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	252	391	392	202	220
Total Alkalinity as CaCO3	----	1	mg/L	252	391	392	202	209
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	9	59	55	35	59
Magnesium	7439-95-4	1	mg/L	5	19	18	19	30
Sodium	7440-23-5	1	mg/L	98	139	138	63	23
Potassium	7440-09-7	1	mg/L	2	1	1	2	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	5.42	10.7	10.5	6.26	6.70
^ Total Cations	----	0.01	meq/L	5.24	10.6	10.3	6.11	6.47
^ Ionic Balance	----	0.01	%	1.76	0.39	1.39	1.17	1.78

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036238-2	GW036314-1	GW036314-2	GW036314-3	GW036541-1
			Client sampling date / time	26-JUL-2009 17:25	23-JUL-2009 13:35	23-JUL-2009 14:05	23-JUL-2009 14:30	23-JUL-2009 10:10
Compound	CAS Number	LOR	Unit	ES0911547-011	ES0911547-012	ES0911547-013	ES0911547-014	ES0911547-015
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	6.23	9420	1070	1040	4840
Sulfate	14808-79-8	0.20	mg/L	8.15	2870	141	138	1360
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	139	413	256	256	335
Total Alkalinity as CaCO3	----	1	mg/L	139	413	256	256	335
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	26	607	42	40	274
Magnesium	7439-95-4	1	mg/L	12	849	48	46	315
Sodium	7440-23-5	1	mg/L	16	6000	749	756	3030
Potassium	7440-09-7	1	mg/L	1	7	2	2	6
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	3.12	334	38.4	37.3	172
^ Total Cations	----	0.01	meq/L	3.03	362	38.6	38.7	172
^ Ionic Balance	----	0.01	%	1.55	3.97	0.38	1.79	0.04

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036541-3	GW036566-1	GW036566-4	GW036600-2	GW036600-3
			Client sampling date / time	23-JUL-2009 11:00	26-JUL-2009 13:50	26-JUL-2009 13:50	24-JUL-2009 15:10	24-JUL-2009 14:15
Compound	CAS Number	LOR	Unit	ES0911547-016	ES0911547-017	ES0911547-018	ES0911547-019	ES0911547-020
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	619	240	249	428	888
Sulfate	14808-79-8	0.20	mg/L	80.0	5.24	5.81	61.1	75.1
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	344	399	373	829	771
Total Alkalinity as CaCO3	----	1	mg/L	344	399	373	829	771
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	17	68	67	59	92
Magnesium	7439-95-4	1	mg/L	13	71	70	71	112
Sodium	7440-23-5	1	mg/L	574	134	135	489	667
Potassium	7440-09-7	1	mg/L	2	3	3	7	10
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	26.0	14.8	14.6	29.9	42.0
^ Total Cations	----	0.01	meq/L	26.9	15.1	15.0	30.2	43.1
^ Ionic Balance	----	0.01	%	1.70	0.97	1.41	0.50	1.25

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	GW036602-1	GW036602-2	GW036602-3	SURFACE 1	SURFACE 2
			Client sampling date / time	24-JUL-2009 16:40	24-JUL-2009 16:20	24-JUL-2009 16:00	23-JUL-2009 17:00	24-JUL-2009 12:25
Compound	CAS Number	LOR	Unit	ES0911547-021	ES0911547-022	ES0911547-023	ES0911547-024	ES0911547-025
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	943	1230	1320	25.0	32.5
Sulfate	14808-79-8	0.20	mg/L	142	434	401	23.7	26.5
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	290	419	598	141	123
Total Alkalinity as CaCO3	----	1	mg/L	290	419	598	141	121
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	42	66	59	24	26
Magnesium	7439-95-4	1	mg/L	62	128	128	15	16
Sodium	7440-23-5	1	mg/L	602	892	1070	22	24
Potassium	7440-09-7	1	mg/L	3	6	7	4	4
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	35.3	52.2	57.4	4.02	3.89
^ Total Cations	----	0.01	meq/L	33.4	52.8	60.2	3.50	3.74
^ Ionic Balance	----	0.01	%	2.80	0.52	2.33	6.86	1.95

Work Order : ES0911547
Client : UNIVERSITY OF NSW
Project : WRL08085 NAMOI

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**SURFACE 3**	**GW036151-1**	**GW036202-1**	----	----
			Client sampling date / time	26-JUL-2009 14:30	30-JUL-2009 08:30	29-JUL-2009 08:30	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES0911547-026**	**ES0911547-027**	**ES0911547-028**	**----**	**----**
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	**68.6**	**4010**	**663**	----	----
Sulfate	14808-79-8	0.20	mg/L	**2.02**	**5120**	**125**	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	**12**	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**393**	**213**	**224**	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**382**	**213**	**224**	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**41**	**561**	**94**	----	----
Magnesium	7439-95-4	1	mg/L	**50**	**496**	**76**	----	----
Sodium	7440-23-5	1	mg/L	**70**	**3480**	**381**	----	----
Potassium	7440-09-7	1	mg/L	**2**	**6**	**2**	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**9.61**	**224**	**25.8**	----	----
^ Total Cations	----	0.01	meq/L	**9.24**	**220**	**27.6**	----	----
^ Ionic Balance	----	0.01	%	**1.99**	**0.80**	**3.35**	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **ES0911733**	Page	: 1 of 7
Client	: **UNIVERSITY OF NSW**	Laboratory	: Environmental Division Sydney
Contact	: MS WENDY TIMMS	Contact	: Charlie Pierce
Address	: WATER RESEARCH LABORATORY KING STREET MANLY VALE NSW, AUSTRALIA 2093	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: w.timms@wrl.unsw.edu.au	E-mail	: charlie.pierce@alsenviro.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: WRL08085 NAMOI	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 07-AUG-2009
Sampler	: DR	Issue Date	: 17-AUG-2009
Site	: ----		
		No. of samples received	: 24
Quote number	: SY/187/09	No. of samples analysed	: 24

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Hoa Nguyen	Inorganic Chemist	Inorganics
Phyu Phyu Lwin	Inorganic Chemist	Inorganics
Wisam Abou-Maraseh	Spectroscopist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ED093F:LCS recovery for Potassium falls outside ALS Dynamic Control Limit. However, it is within the acceptance criteria based on ALS DQO. No further action is required.**

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	GW030061-1	GW030136-1	GW030168-1	GW030168-2	GW030238-1
			Client sampling date / time	30-JUL-2009 16:20	27-JUL-2009 11:25	27-JUL-2009 13:05	27-JUL-2009 13:35	27-JUL-2009 15:45
Compound	CAS Number	LOR	Unit	ES0911733-001	ES0911733-002	ES0911733-003	ES0911733-004	ES0911733-005
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	279	50.6	9.83	14.9	59.2
Sulfate	14808-79-8	0.20	mg/L	10.0	45.7	14.0	14.0	75.2
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	324	203	154	162	185
Total Alkalinity as CaCO3	----	1	mg/L	324	203	154	162	185
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	10	59	26	32	56
Magnesium	7439-95-4	1	mg/L	18	24	18	19	29
Sodium	7440-23-5	1	mg/L	268	30	18	15	45
Potassium	7440-09-7	1	mg/L	3	<1	1	1	<1
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	14.5	6.43	3.64	3.95	6.93
^ Total Cations	----	0.01	meq/L	13.8	6.25	3.57	3.82	7.10
^ Ionic Balance	----	0.01	%	2.82	1.48	1.08	1.63	1.21

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	GW030000-1	GW036130-1	GW036151-2	GW036166-1	GW036166-2
			Client sampling date / time	29-JUL-2009 13:50	29-JUL-2009 15:40	30-JUL-2009 10:45	28-JUL-2009 17:00	28-JUL-2009 16:40
Compound	CAS Number	LOR	Unit	ES0911733-006	ES0911733-007	ES0911733-008	ES0911733-009	ES0911733-010
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	123	866	1230	1770	1510
Sulfate	14808-79-8	0.20	mg/L	28.6	223	396	4380	2620
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	332	256	192	541	582
Total Alkalinity as CaCO3	----	1	mg/L	332	256	192	541	582
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	48	33	126	300	185
Magnesium	7439-95-4	1	mg/L	37	46	74	328	234
Sodium	7440-23-5	1	mg/L	102	593	727	2240	1660
Potassium	7440-09-7	1	mg/L	2	1	3	3	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	10.7	34.2	46.8	152	109
^ Total Cations	----	0.01	meq/L	9.94	31.3	44.1	139	101
^ Ionic Balance	----	0.01	%	3.77	4.43	3.02	4.34	3.76

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036166-3	GW036190-1	GW036200-2	GW036200-3	GW036210-1
			Client sampling date / time	28-JUL-2009 16:05	29-JUL-2009 12:30	29-JUL-2009 16:40	29-JUL-2009 17:05	29-JUL-2009 10:00
Compound	CAS Number	LOR	Unit	ES0911733-011	ES0911733-012	ES0911733-013	ES0911733-014	ES0911733-015
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	70.0	406	138	186	1310
Sulfate	14808-79-8	0.20	mg/L	37.5	355	59.8	63.6	190
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	268	373	453	445	1000
Total Alkalinity as CaCO3	----	1	mg/L	268	373	453	445	1000
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	26	57	116	126	422
Magnesium	7439-95-4	1	mg/L	11	58	39	42	142
Sodium	7440-23-5	1	mg/L	129	383	92	98	538
Potassium	7440-09-7	1	mg/L	1	2	1	1	3
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	8.11	26.3	14.2	15.4	61.0
^ Total Cations	----	0.01	meq/L	7.87	24.3	13.0	14.0	56.3
^ Ionic Balance	----	0.01	%	1.54	3.89	4.28	4.96	4.00

Analytical Results

Sub-Matrix: WATER			Client sample ID	GW036210-3	GW036238-1	GW036238-4 GW036238-3	GW040822-1	SURFACE 4
			Client sampling date / time	29-JUL-2009 09:15	27-JUL-2009 16:23	28-JUL-2009 09:25	30-JUL-2009 15:00	27-JUL-2009 11:30
Compound	CAS Number	LOR	Unit	ES0911733-016	ES0911733-017	ES0911733-018	ES0911733-019	ES0911733-020
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	129	69.2	16.1	2000	58.0
Sulfate	14808-79-8	0.20	mg/L	41.4	44.4	16.3	426	37.4
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	730	950	272	252	197
Total Alkalinity as CaCO3	----	1	mg/L	730	950	272	252	197
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	162	106	29	84	47
Magnesium	7439-95-4	1	mg/L	46	99	21	217	27
Sodium	7440-23-5	1	mg/L	133	156	65	1200	36
Potassium	7440-09-7	1	mg/L	3	4	2	3	2
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	19.1	21.8	6.23	70.4	6.35
^ Total Cations	----	0.01	meq/L	17.8	20.3	6.07	74.4	6.19
^ Ionic Balance	----	0.01	%	3.55	3.64	1.29	2.70	1.29

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**SURFACE5**	**SURFACE 6**	**SURFACE 7**	**SURFACE 8**	----
			Client sampling date / time	27-JUL-2009 13:30	29-JUL-2009 13:10	30-JUL-2009 11:10	30-JUL-2009 12:00	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES0911733-021**	**ES0911733-022**	**ES0911733-023**	**ES0911733-024**	----
ED009: Anions								
Chloride	16887-00-6	0.20	mg/L	**5.34**	**139**	**126**	**128**	----
Sulfate	14808-79-8	0.20	mg/L	**7.38**	**7.97**	**6.58**	**6.64**	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**70**	**379**	**371**	**373**	----
Total Alkalinity as CaCO3	----	1	mg/L	**70**	**379**	**371**	**373**	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**12**	**39**	**42**	**42**	----
Magnesium	7439-95-4	1	mg/L	**8**	**68**	**66**	**67**	----
Sodium	7440-23-5	1	mg/L	**12**	**68**	**63**	**63**	----
Potassium	7440-09-7	1	mg/L	<1	**3**	**3**	**4**	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**1.70**	**11.6**	**11.1**	**11.2**	----
^ Total Cations	----	0.01	meq/L	**1.78**	**10.6**	**10.4**	**10.4**	----
^ Ionic Balance	----	0.01	%	----	**4.56**	**3.44**	**3.42**	----

APPENDIX A9
FACT SHEET – DIY GROUNDWATER MONITORING

DIY Groundwater Monitoring

Groundwater Series: Skills & Knowledge | Fact Sheet 5 | Produced by Cotton Catchment Communities CRC and UNSW Water Research Laboratory

What to monitor ?

Groundwater level should be measured from a standard reference point such as ground level or the top of casing.

Water salinity can be monitored simply by an EC meter (electrical conductivity). Water salinity should also be periodically analysed by a laboratory to measure concentration of sodium, calcium, magnesium, chloride, sulphate and bicarbonate salts. Full laboratory analysis can be used to check more frequent EC measurements.

Other basic water quality tests are nitrate and E.Coli, an indicator of bacterial contamination. Note there are hundreds of water quality parameters that can be tested depending on the intended use of water.

What equipment is needed ?

1. Access point for monitoring on the bore casing and preferably a dip tube installed next to the pump main (Figure 1). A monitoring dip tube can be made from a 25 mm PVC tube, with slotted sections near the base and should be installed with the pump, and also in the gravel pack outside the bore casing.

2. Measuring tape and "dipper" device. Alternatively, a commercial dip meter provides more accurate data.

3. Basic EC meter & clean measuring cup.

How often to monitor ?

Groundwater level – weekly during pumping season, monthly at other times. A consistent record over many years is most important.

Water salinity (EC) – monthly during pumping season.

Water salinity (major salt ions) – once per year, preferably during the non pumping season.

If there is a change in groundwater levels or salinity then professional hydrogeological advice should be obtained. Further assessment is required if the change is larger than previous variations, or there is a consistent pattern of falling groundwater levels or increasing salinity.

What to do with the data ?

Data can be recorded on the attached form.

If there is a change in groundwater levels or salinity then professional hydrogeological advice should be obtained. Further assessment is required if the change is larger than previous variations, or there is a consistent pattern of falling groundwater levels or increasing salinity.

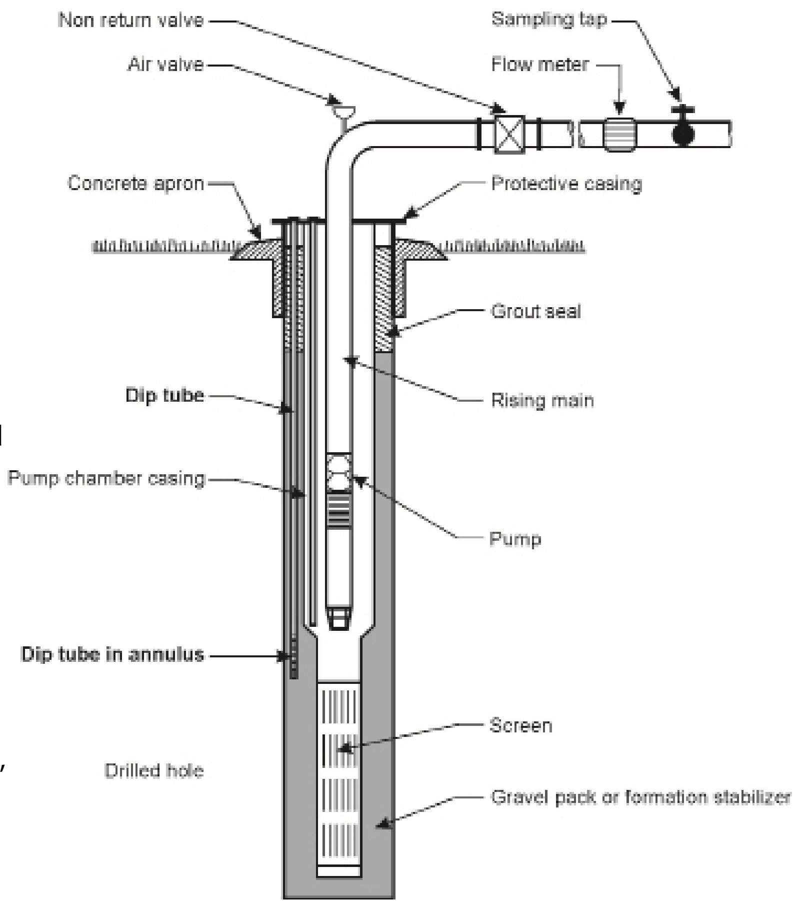


Figure 1 – Monitoring dip tubes in an irrigation bore

Fact sheet modified after Timms, W., 1997. The Liverpool Plains Water Quality Project: 1996/97 Report on Groundwater Quality. Department of Land and Water Conservation, Centre for Natural Resources, CNR 97.108.

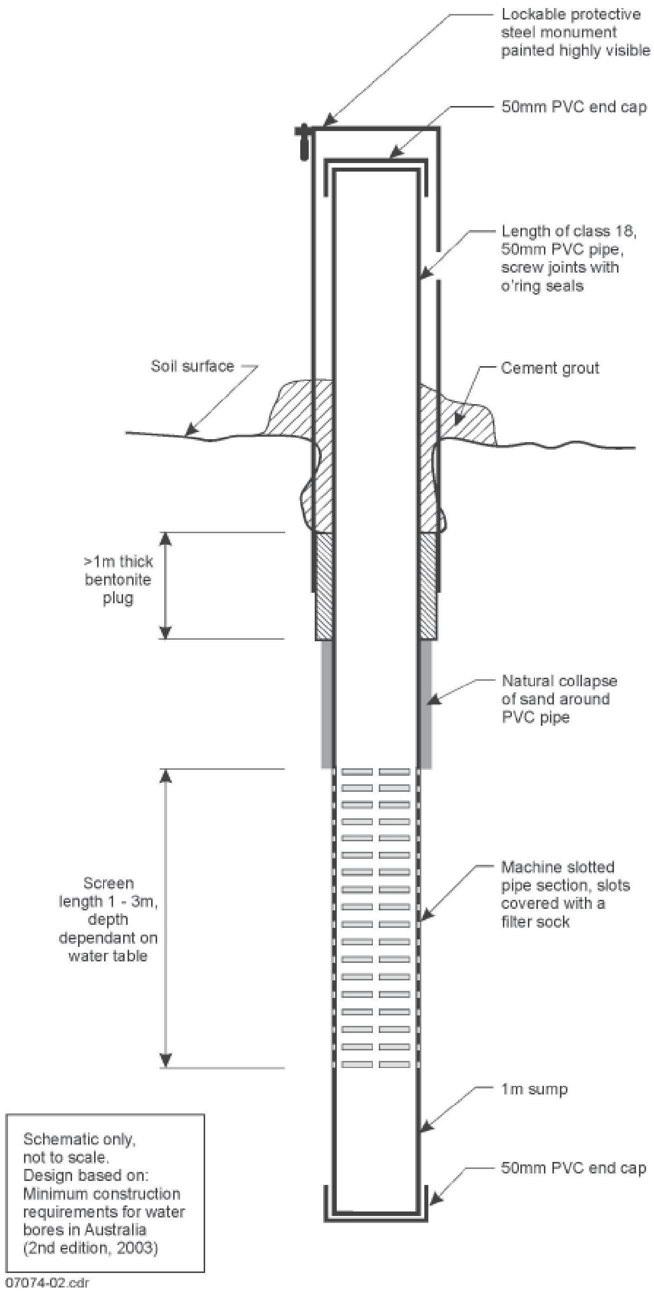


Figure 2– Groundwater monitoring piezometer

What is a piezometer ?

A piezometer is a specially designed bore with a short intake screen to monitoring groundwater levels at a specific point in an aquifer. Ideally, monitoring should be undertaken in both irrigation bores and piezometers.

Figures 2 and 3 show how to construct a shallow monitoring piezometer and the materials that are required.

Shallow piezometers can be installed in an auger hole to about 5 m depth. Deep piezometers require a drilling rig and specialised materials to prevent leakage between different aquifer systems.

Figure 3 – Materials to install a shallow monitoring piezometer

How much does monitoring cost ?

Your time is the most significant cost. Keep in mind the costs of not monitoring the water that you use could be incalculable. Basic monitoring equipment can be purchased from companies such as www.enviroequip.com For example, a fox whistle (~$120) can be attached to a tape measure for water level measurement, or a electronic dip meter can be purchased (~$600). A basic pocket EC meter costs about $150 (Figure 4).

Figure 4 – Example of water level dipper and pocket sized salinity EC meter.

A NATA certified laboratory should be contacted for current prices. A rough guide for EC and major salt ions is about $50 per sample, and about $20 per sample for nutrients. Labs can advise about suitable methods and bottles to use to ensure that the data is reliable.

Cotton Catchment Communities CRC

Australian Government
Department of Agriculture, Fisheries and Forestry
National Landcare Programme

University of New South Wales
School of Civil & Environmental Engineering
Water Research Laboratory

GROUNDWATER LEVEL MONITORING DATA SHEET

Property name:	Postal address:
Contact person:	Phone:

Bore Number & Location	1	2	3
Bore depth (m below ground level)			
Pipe height (m above ground level)			
Slotted interval (m below ground level)			

It is recommended that water levels be measured at least every 2 months, and every week during irrigation pumping.

Bore	1		2		3		
Date	SWL (m top pipe)	EC (mS/cm)	SWL (m top pipe)	EC (mS/cm)	SWL (m top pipe)	EC (mS/cm)	Comments (e.g. rainfall, landuse change, harvest)

APPENDIX A10
DATABASE STANDARDS AND INFORMATION

APPENDIX A10: DATABASE STANDARDS AND INFORMATION

WRL has created two databases of information for the Namoi catchment – one for water quality and one for water levels. The database is being developed by WRL in MS ACCESS, with pre and post processing of data using Python scripts and quality checking and correcting where possible.

WATER QUALITY DATABASE

Data Sources

The water quality database includes data from the following sources:

- Sampling for this project in January, March and July 2009
- Triton – DECCW internal groundwater database for historic data
- McLean (2003) PhD thesis (Lower Namoi Alluvium)
- Timms et al (in prep) (Upper Mooki -Zone 8)
- Andersen & Acworth (2007) (Maules Creek -Zone 11)
- Lavitt (1999) PhD thesis (Lower Mooki -Zone 3)
- Bradd et al (1994) (Mooki -Zone 3,8)
- Acworth & Timms (2002) (Pullaming)
- Waite, Jankowski and Acworth (1995) (Coxes Creek)

Note that grower sample data provided during this project is not included in the database.

The following issues with data availability were encountered during construction of the database:

- Much historic data is incomplete – in many cases the screen depths of bores (and therefore aquifer penetrated) is unknown. Much of the data collected prior to the mid-1990s has been stored without the Pipe number, and therefore cannot be used.
- Poor data collection procedures – samples collected without adequate purging, field measurements or reference levels
- Poor data management systems – data collected by various stakeholder organisations has been lost or poorly archived without metadata; data is difficult to access.

Database Basis

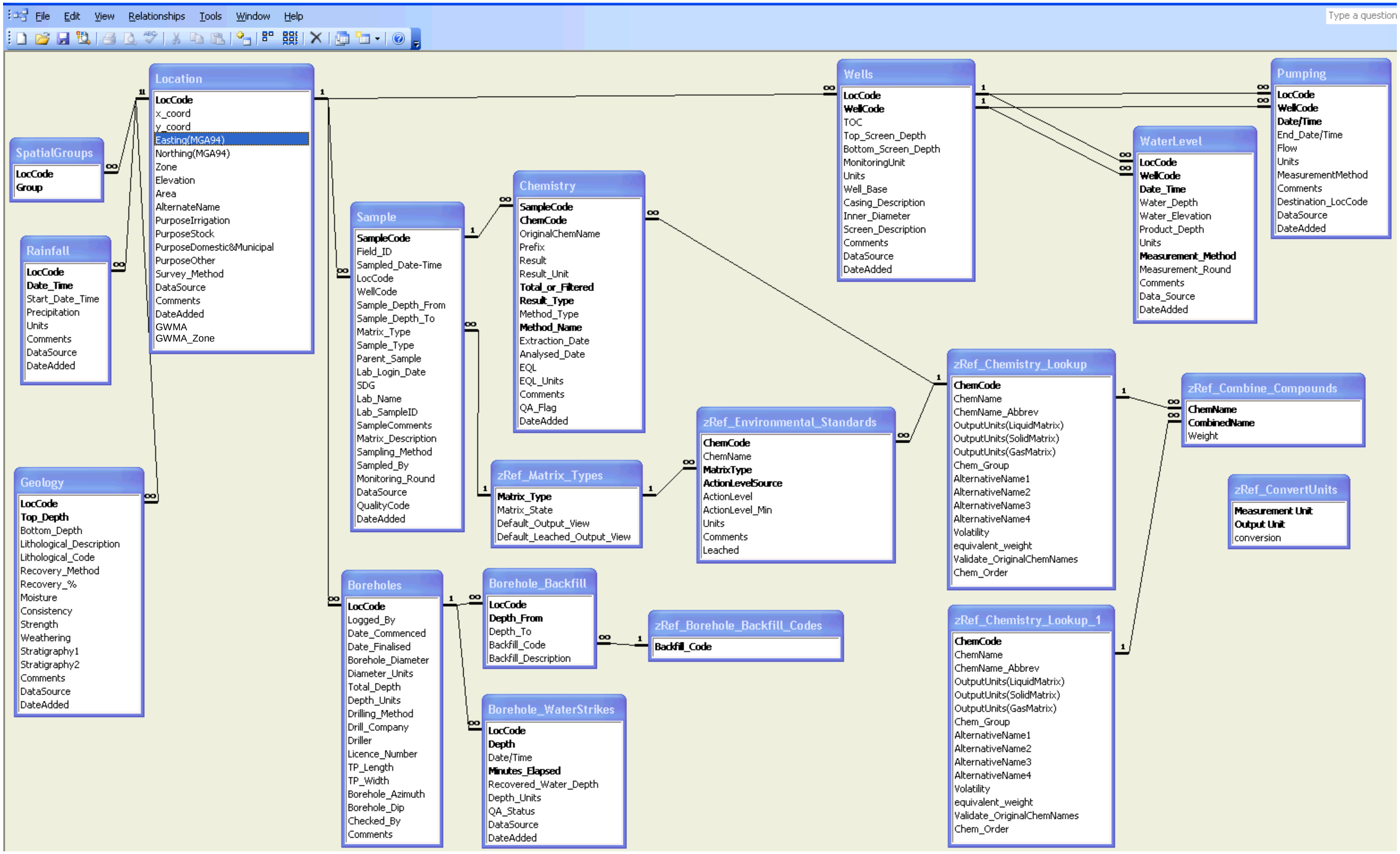
The water quality database was created using the ESdat interface for MS Access (Earth Science Information Systems Pty. Ltd.) and can be used either with ESdat or directly in MS

Access. ESdat allows user flexibility and therefore a number of new database fields were created to improve the functionality of the database for the Namoi Catchment

Database Structure

The main tables and relationships between this tables are shown in the following schematic. The full functionality of ESdat has not been used for the construction of this database due to the data available. As such, the relationship schematic shows the key tables and relationships. All default tables within ESdat have been maintained within the database should the need for further database expansion arise.

All tables with the prefix zRef_ are reference tables containing information not specific to this database, such as chemical data (zRef_Chemistry_Lookup).


File Edit View Relationships Tools Window Help
Type a question
Location
LocCode
x_coord
y_coord
Easting(MGA94)
Northing(MGA94)
Zone
Elevation
Area
AlternateName
PurposeIrrigation
PurposeStock
PurposeDomestic&Municipal
PurposeOther
Survey_Method
DataSource
Comments
DateAdded
GWMA
GWMA_Zone
SpatialGroups
LocCode
Group
Rainfall
LocCode
Date_Time
Start_Date_Time
Precipitation
Units
Comments
DataSource
DateAdded
Geology
LocCode
Top_Depth
Bottom_Depth
Lithological_Description
Lithological_Code
Recovery_Method
Recovery_%
Moisture
Consistency
Strength
Weathering
Stratigraphy1
Stratigraphy2
Comments
DataSource
DateAdded
Sample
SampleCode
Field_ID
Sampled_Date-Time
LocCode
WellCode
Sample_Depth_From
Sample_Depth_To
Matrix_Type
Sample_Type
Parent_Sample
Lab_Login_Date
SDG
Lab_Name
Lab_SampleID
SampleComments
Matrix_Description
Sampling_Method
Sampled_By
Monitoring_Round
DataSource
QualityCode
DateAdded
Chemistry
SampleCode
ChemCode
OriginalChemName
Prefix
Result
Result_Unit
Total_or_Filtered
Result_Type
Method_Type
Method_Name
Extraction_Date
Analysed_Date
EQL
EQL_Units
Comments
QA_Flag
DateAdded
zRef_Matrix_Types
Matrix_Type
Matrix_State
Default_Output_View
Default_Leached_Output_View
zRef_Environmental_Standards
ChemCode
ChemName
MatrixType
ActionLevelSource
ActionLevel
ActionLevel_Min
Units
Comments
Leached
Wells
LocCode
WellCode
TOC
Top_Screen_Depth
Bottom_Screen_Depth
MonitoringUnit
Units
Well_Base
Casing_Description
Inner_Diameter
Screen_Description
Comments
DataSource
DateAdded
WaterLevel
LocCode
WellCode
Date_Time
Water_Depth
Water_Elevation
Product_Depth
Units
Measurement_Method
Measurement_Round
Comments
Data_Source
DateAdded
Pumping
LocCode
WellCode
Date/Time
End_Date/Time
Flow
Units
MeasurementMethod
Comments
Destination_LocCode
DataSource
DateAdded
zRef_Chemistry_Lookup
ChemCode
ChemName
ChemName_Abbrev
OutputUnits(LiquidMatrix)
OutputUnits(SolidMatrix)
OutputUnits(GasMatrix)
Chem_Group
AlternativeName1
AlternativeName2
AlternativeName3
AlternativeName4
Volatility
equivalent_weight
Validate_OriginalChemNames
Chem_Order
zRef_Combine_Compounds
ChemName
CombinedName
Weight
zRef_ConvertUnits
Measurement Unit
Output Unit
conversion
Boreholes
LocCode
Logged_By
Date_Commenced
Date_Finalised
Borehole_Diameter
Diameter_Units
Total_Depth
Depth_Units
Drilling_Method
Drill_Company
Driller
Licence_Number
TP_Length
TP_Width
Borehole_Azimuth
Borehole_Dip
Checked_By
Comments
Borehole_Backfill
LocCode
Depth_From
Depth_To
Backfill_Code
Backfill_Description
zRef_Borehole_Backfill_Codes
Backfill_Code
Borehole_WaterStrikes
LocCode
Depth
Date/Time
Minutes_Elapsed
Recovered_Water_Depth
Depth_Units
QA_Status
DataSource
DateAdded
zRef_Chemistry_Lookup_1
ChemCode
ChemName
ChemName_Abbrev
OutputUnits(LiquidMatrix)
OutputUnits(SolidMatrix)
OutputUnits(GasMatrix)
Chem_Group
AlternativeName1
AlternativeName2
AlternativeName3
AlternativeName4
Volatility
equivalent_weight
Validate_OriginalChemNames
Chem_Order

Data Tables

The main data entry tables used for this database are described below. Descriptions of each field have been written into the Description field in the design view of the table and display at the bottom of each table as data is entered. Where appropriate, data validation has been used to limit the data entry into the fields to ensure the integrity of the database. Reference tables (with prefix zRef) have not been described as it is assumed that there will be no need to change these.

Table	Description
Chemistry	Individual line items for each analyte result. Every item must be associated with a Sample.
Geology	Contains drill log information where available. Geological data from the DECCW database was summarised into a limited number of relevant lithological codes for consistency.
Location	This is the parent table that lists bore numbers and location details for the bores, from which all other data tables are related. Data related to a location in another must have an equivalent entry in this table.
Sample	This is the parent table for water quality data and contains all of the sample metadata.
SpatialGroups	Used to group locations. Locations can belong to multiple spatial groups. WRLTargetBores is the spatial group that contains all the bores used in the monitoring program
WaterLevel	Water level measurements. Only contains WRL measurements at this time.
Wells	Contains the well construction information for each location and pipe number (where available), such as screen depth, casing etc. Also contains the monitoring unit information.

Custom Database Fields

The following fields were added to the database structure:

Field	Data Source
GWMA	Groundwater Management Area based on ArcGIS analysis of bore locations
GWMA_Zone	Groundwater Management Area Zone (for Upper Namoi Alluvium) based on ArcGIS analysis of bore locations
EastingMGA94	Easting in projection MGA 94
NorthingMGA94	Northing in projection MGA 94
Zone	Projection Zone
Monitoring Unit	Based on connectivity analysis
Purpose	The purposes for the bores in the DWE database were condensed and summarised to allow greater searching and filtering functionality. Four fields were established for Purpose with a hierarchy determined by those purposes most relevant to the groundwater monitoring program ie. Irrigation, Stock, Domestic& Municipal and Other, where the hierarchy of presentation for Other was 1. Monitoring&Test 2. Mining&Exploration 3. Commercial&Industrial 4.Aquaculture 5.ArtificialRecharge 6.WasteDisposal

Data Quality Control

The following quality control procedures are built into the database:

- Data validation for fields where appropriate
- Links to specified reference tables that limit the data that can be input.

Database Functions:

ESdat provides a number of queries inbuilt into the database structure for viewing the data in different ways. WRL have added the following queries to the database:

- ECTrend – Averages EC data for a specified range of sampled_date_times for each pipe of each bore
- ECTrendMonitoringUnit- Averages EC data for a specified range of sampled_date_times for each monitoring unit for each bore. Data only output for those bores where monitoring unit is specified.
- WRLTargetBoresECTable – outputs all available EC data for the WRL target monitoring bores.

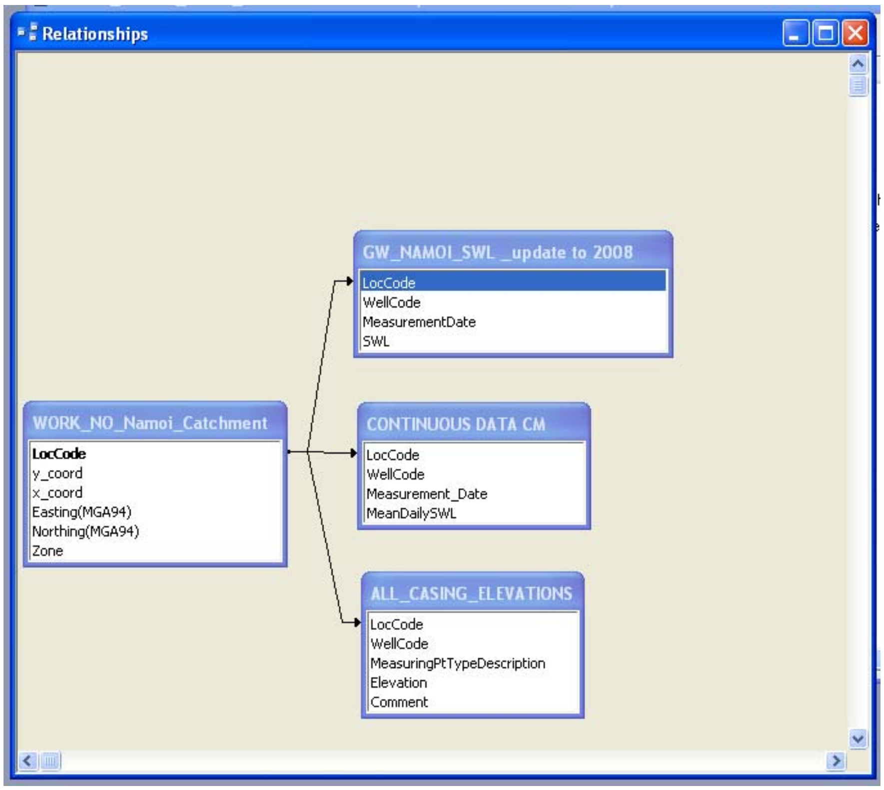
WATER LEVEL DATABASE

Data Sources

Water level data was sourced from DECCW's archive CD with additional data provided upon request up to November 2008.

Database Basis & Structure

The database was created in MS Access and has a very simple structure as seen in the following Relationships diagram. Data field titles have been adjusted for consistency with the water quality database.



Data Tables

There are four data tables contained in the water level database as follows:

Table	Description
ALL_CASING_ELEVATIONS	Contains elevations of each pipe for each monitoring bore and the measurement point of that elevation. The elevation is either from the DECCW where available or has been interpolated from the DEM.
CONTINUOUS_DATA_CM	Water level data from telemetry sites acquired from DECCW.
GW_NAMOI_SWL _update to 2008	Data from DECCW Pinneena Groundwater CD v2.1 (May, 2007) with additional updated data up to November 2008.
WORK_NO_Namoi_Catchment	Bore numbers and locations for all of the bores in the Namoi Catchment.

Continuous monitoring data has been kept separate from the other groundwater level monitoring program data. All other relevant data regarding geology and bore construction can be found in the Water Quality Database.

Data Quality Control

Data was limited to the Namoi Catchment and the following quality control procedures:

- Removal of duplicate data
- Addition of elevation data using GIS interpolation. Elevation was cross-checked against measured values both from WRL field work and the DECCW database and was found to be accurate within ± 1m. While the DEM is not generally considered to be this accurate due to interference with trees etc, the location of the majority of bores on the plains decreases the error of the analysis.

APPENDIX A11
PRESENTATION SLIDES FROM GROWER WORKSHOP

Cotton Catchment Communities CRC

Namoi CMA CATCHMENT MANAGEMENT AUTHORITY

Namoi monitoring and evaluation & grower survey – Namoi catchment

Grower Workshops
31st August & 1st September

Dr Wendy Timms and WRL Projects team
Ingrid Roth & GHD Hassall team

UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

GHD CLIENTS PEOPLE PERFORMANCE
GHD Hassall

Consulting, Research & Training Services to Industry & Government since 1959

Acknowledging the support of key stakeholders

Participation and support has been essential!

Namoi Water – support for inception of project, support of growers in sampling, organising and promoting meeting/workshops

NSW Farmers – support for inception & sampling

Cotton Australia – support for inception & sampling

NSW DECCW – support for inception, access to monitoring bores, provision of data

UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

Outline of Preliminary Results

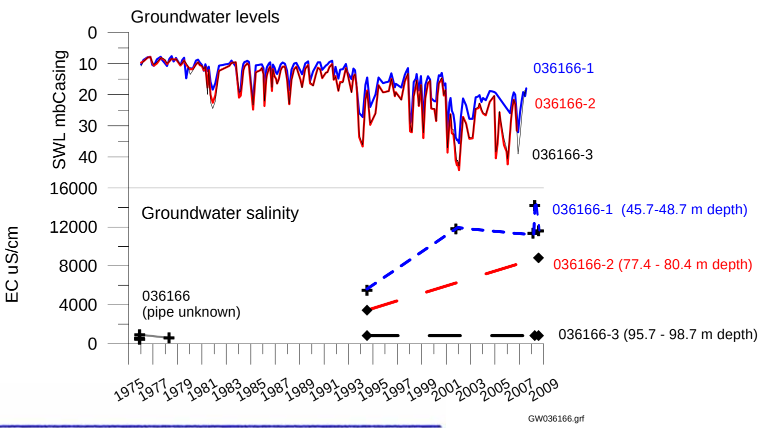
- Why monitor ?
- Groundwater level changes

- Groundwater salinity changes
- “Groundwater Sampling in July” by growers

- Setting targets for groundwater

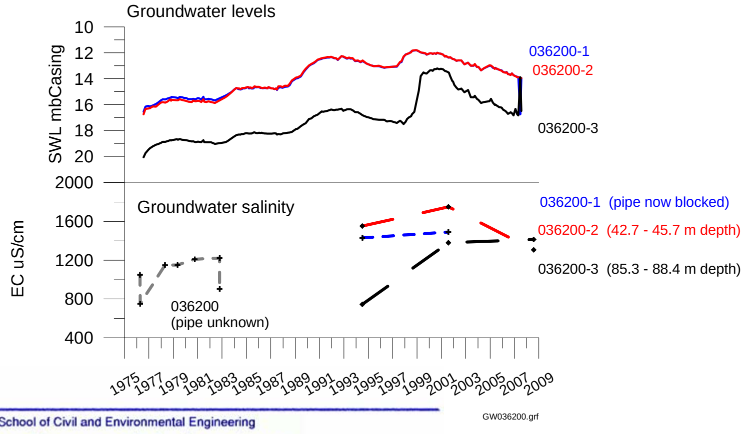
Why monitor?

- At one site in the Namoi, groundwater at 80 m depth has become too saline for irrigation of cotton (7,700 µS/cm ANZECC). Was a fresh alluvial aquifer.
- Change occurred sometime between mid and late1990s
- Salinity change associated with <u>decreased</u> groundwater levels?



Why monitor?

- At another site, groundwater at 80 m depth has become marginal for irrigation of young cotton (1,500 µS/cm)
- Change occurred sometime between mid and late1990s
- Salinity change associated with increased groundwater levels?
- Pipe 1 now blocked – possibly casing corroded and collapsed



Monitoring Plan

Focus on groundwater levels and salinity – not nutrients & agrichemicals
Focus on alluvial aquifers

1. Sampling of irrigation/stock bores by growers

- "Groundwater Sampling in July"
- Very valuable for "point of use" salinity info
- Optimal time for scientific sample of recovered conditions
- Logistically more challenging – have to turn on bores during winter
- Generally not possible to measure groundwater levels
- Some uncertainty regarding depth of sampling, purging etc.

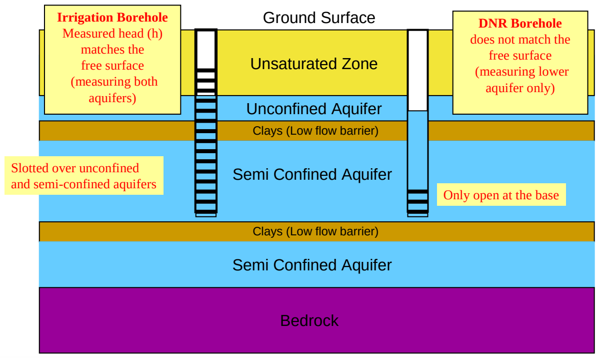
2. Sampling of monitoring bores by WRL

- Sampling of monitoring bore in January, March and July 2009
- Timing to coincide with maximum stress, recovering, and recovered conditions
- Groundwater level and field EC, temperature and pH
- Selected samples for major ion analysis
- AUS/NZ Standard methods for sampling & analysis - eg. purging of bores, sample holding/chilling

Groundwater monitoring

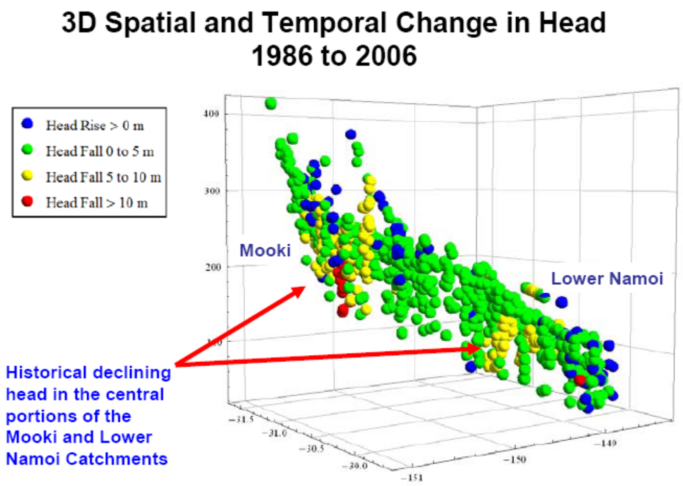
Pumping bore
- Important to monitor levels & salinity at “point of use”
- long screens, multiple aquifers
- “average” water level & quality
- some details unknown

Monitoring bore
- short screen, narrow pipe
- details known for purging of representative samples
- can have nested pipes each in specific aquifer



Courtesy of Bryce Kelly

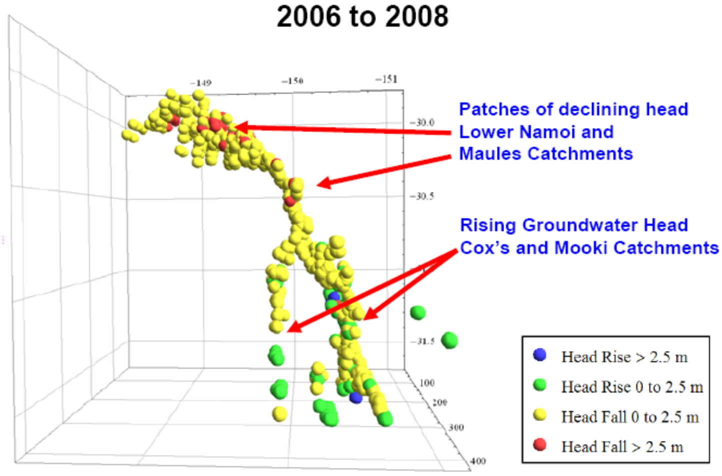
Groundwater levels



Courtesy of Bryce Kelly and CWI project

Groundwater levels

3D Spatial and Temporal Change in Head 2006 to 2008

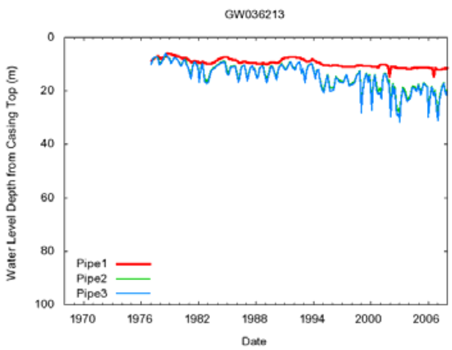


Courtesy of Bryce Kelly and CWI project

Groundwater levels – to mid 2008

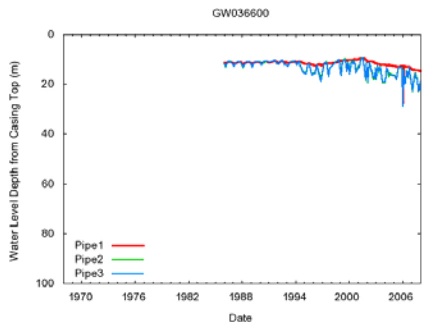
Zone 3 – Western side of Battery Hill

- Long term decline, recent stablisation
- Pipe 1: 19-22 m
- Pipe 2: 38-41 m
- Pipe 3: 55-58 m



Zone 2 - Lower Coxes Creek

- Long term decline
- Pipe 1: 13-15 m
- Pipe 2: 100-105 m
- Pipe 3: 122-127 m

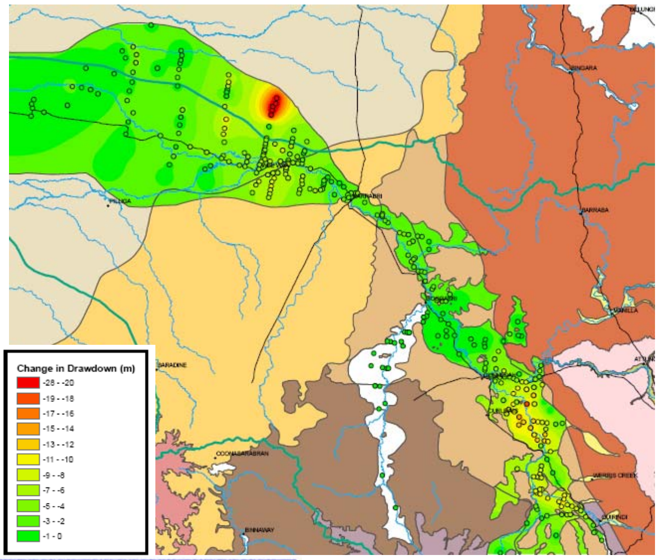


Draft results – Groundwater levels 1978 to 2004

Recovered drawdown 1978 to mid-2004

Long term drawdown

Upper aquifer (connectivity method)



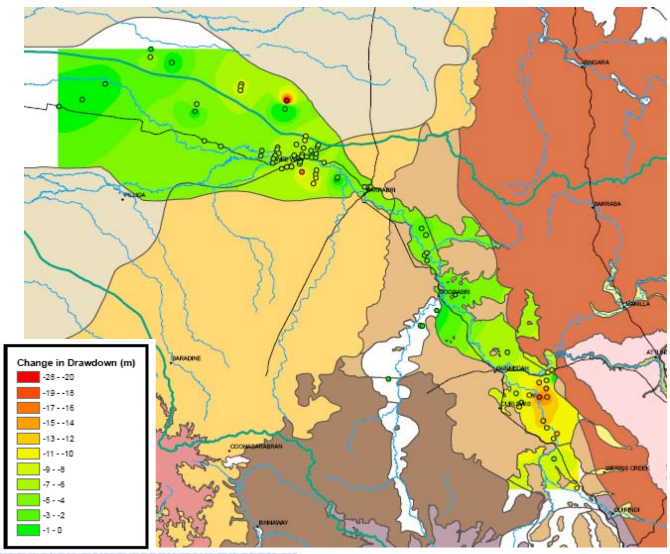
UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

Draft results – Groundwater levels 1978 to 2004

Recovered drawdown 1978 to mid-2004

Long term drawdown

Lower aquifer (connectivity method)



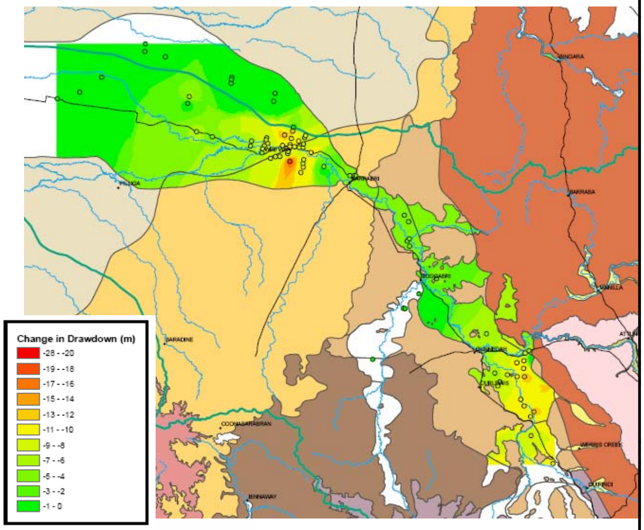
UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

Draft results – Groundwater levels   1978 to 2008

Recovered drawdown 1978 to mid-2008

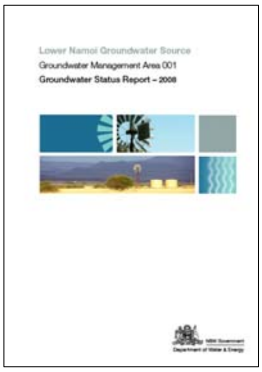
Orange/yellow – long term drawdown

Lower aquifer (connectivity method)



Status of groundwater monitoring in the Namoi

- **Groundwater licence holders** – condition to provide water quality results
- **DECCW monitoring bores**
  - 305 in Upper Namoi, 258 in Lower Namoi
  - more sites in fractured rock & Peel/Manilla areas ?
- **DECCW monitoring of groundwater levels**
  - Quarterly by manual dip
  - Automated logging at new telemetry sites
    - 47 sites and 66 pipes
- **Long term plans for information to be available on web**
  www.bom.gov.au/water
- **Groundwater quality monitoring - limited**
  Currently 20 sites - Cryon
  New NWC project – Zone 3 Upper Namoi
  Liverpool Plains Water Quality Project 1996-1999

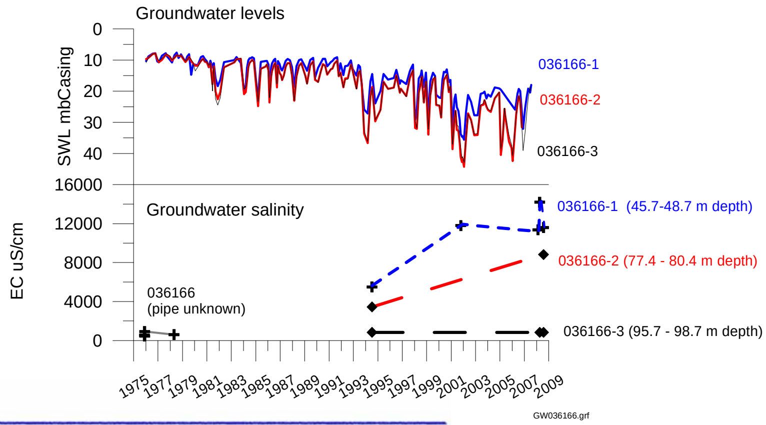

Lower Namoi Groundwater Source
Groundwater Management Area 001
Groundwater Status Report – 2008

Plus various local research projects by UNSW etc.

UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

Why monitor?

- At one site in the Namoi, groundwater at 80 m depth has become too saline for irrigation of cotton (7,700 µS/cm ANZECC). Was a fresh alluvial aquifer.
- Change occurred sometime between mid and late1990s
- Salinity change associated with <u>decreased</u> groundwater levels?

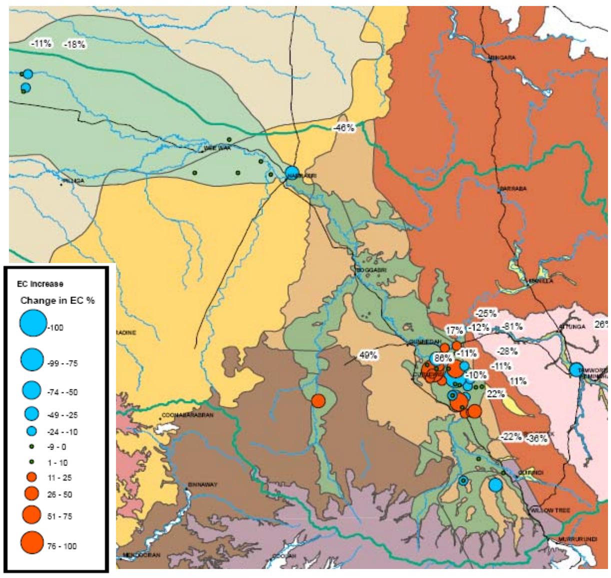


Draft results – Groundwater Salinity Changes

$EC_{average}$ 1980-1999
$EC_{average}$ 2000-2009

No. of GW pipes
673 total pipes
105 with available data
- 57 EC stable
- 21 EC up >10%
- 27 EC down >10%

This map Pipe 1 only (shallowest)



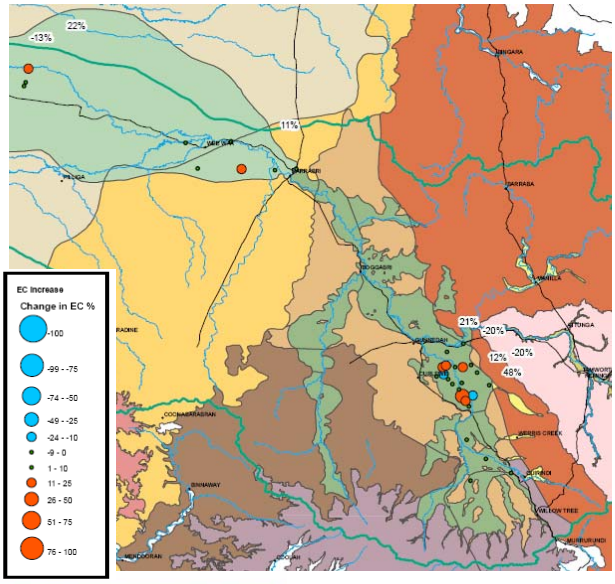
UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

Draft results – Groundwater Salinity Changes

$EC_{average}$ 1980-1999
$EC_{average}$ 2000-2009

No. of GW pipes
673 total pipes
105 with available data
- 57 EC stable
- 21 EC up >10%
- 27 EC down >10%

This map Pipe 2

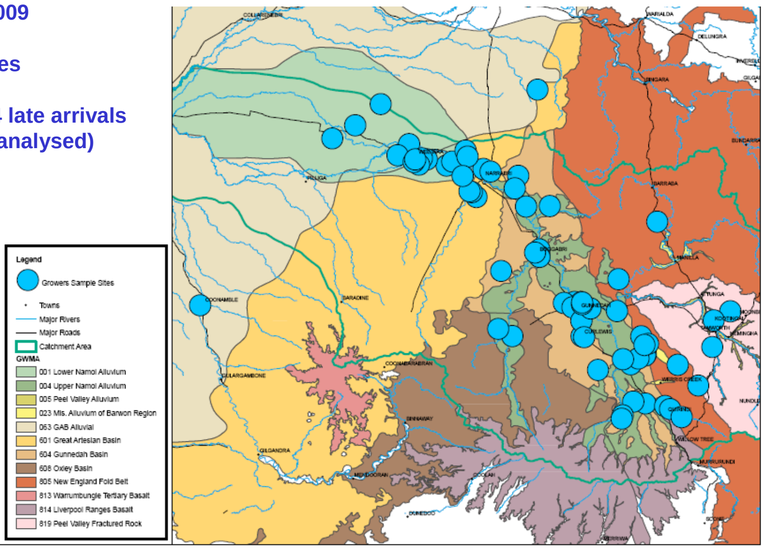


Grower Sample Sites

July 2009

69 bores

(plus 4 late arrivals being analysed)



How to read your bore water quality report

		Electrical conductivity	TDS	Sodium	Calcium	Potassium	Magnesium	Chloride	Sulphate	Bicarbonate	Carbonate	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Sodium Absorption Ratio	Hardness as CaCO3	Anions Total	Cations Total	Ionic Balance
		uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	units	mg/L	meq/L	meq/L	%
EQL		1		1	1	1	1	0.2	0.2	1	1	1000	1			0.01	0.01	0.01
ANZECC2000				**600[#9]**				**1000[#7]**						**102[#6]**	**350[#15]**			
ANZECC-Barley		*8000[#5]*																
ANZECC-Beef Cattle			10000[#14]															
ANZECC-Cotton		7700[#4]																
ANZECC-Dairy Cattle			7000[#13]															
ANZECC-Irrigation-General								750[#8]										
ANZECC-Irrigation-Specified				460[#18]				700[#18]										
ANZECC-Pigs			8000[#12]															
ANZECC-Poultry			4000[#11]															
ANZECC-Sheep			13000[#10]															
ANZECC-Stock							2000[#20]		1000[#19]									
ANZECC-Stock-Risk									2000[#17]									
ANZECC-Sunflower		5500[#2]																
ANZECC-Wheat		6000[#1]																
Australian Drinking Water			500[#3]	180[#3]				250[#3]	250[#3]						200[#3]			
Early Season Cotton		1500[#16]																
Field_ID	**Sampled_Date-Time**																	
G1	10/07/2009	7590	4724	**1630**	40	7	46	**2060**	217	724	<1	<1000	724	42	289	77.2	77.1	0.1

Comments
#1 Unsuitable for Wheat irrigation.
#2 Unsuitable for Sunflower irrigation.
#3 Unsuitable for drinking.
#4 Unsuitable for Cotton irrigation.
#5 Unsuitable for Barley irrigation.
#6 Stunted growth for Cotton and Sunflower
#7 Risk to cotton growth.
#8 Risk of increased Cadmium intake by crops.
#9 Non-satisfactory for stock.
#10 Loss of production and a decline in sheep condition and health.
#11 Loss of production and a decline in poultry condition and health.
#12 Loss of production and a decline in pigs condition and health.

UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

Draft results – Groundwater Sampling in July

Aiming for 200 samples by growers (300 sample packs to distribution points)

Total of 69 samples received by 13th of August.
- 36 samples in Upper & Lower Namoi alluvial aquifers
- 31 samples in Misc. alluvial aquifers and fractured Rock aquifers
- 2 samples outside Namoi catchment

GWMA	No. samples	EC (µS/cm)		
		Min	max	average
(001) Lower Namoi Alluvial	16	427	7590	1623
(004) Upper Namoi Alluvium - Zone 2	1	580	580	580
(004) Upper Namoi Alluvium - Zone 3	3	452	758	574
(004) Upper Namoi Alluvium - Zone 4	7	340	2230	798
(004) Upper Namoi Alluvium - Zone 5	2	960	2470	1715
(004) Upper Namoi Alluvium - Zone 6	2	853	2000	1427
(004) Upper Namoi Alluvium - Zone 7	1	1270	1270	1270
(004) Upper Namoi Alluvium - Zone 8	3	693	1240	947
(004) Upper Namoi Alluvium - Zone 11	1	674	674	674
	36			

UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

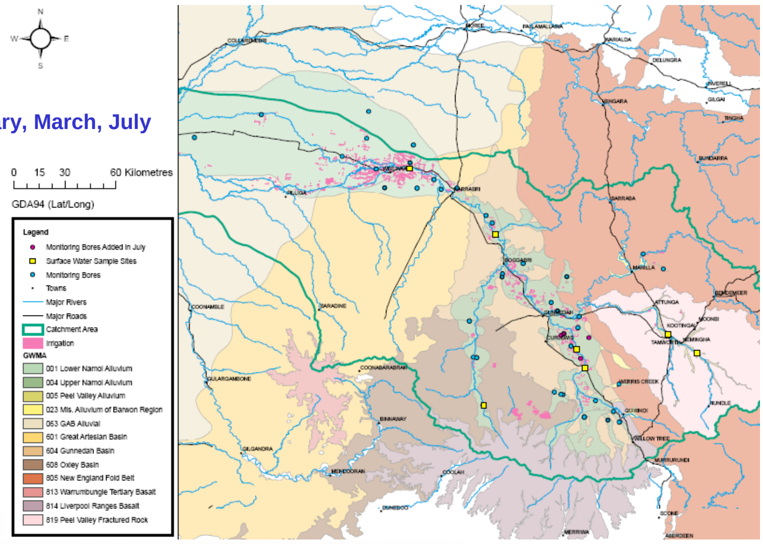
Draft results – Groundwater Sampling in July

- Samples spread widely – includes fractured rock areas that WRL did not sample
- Samples spread thinly – only a few samples in each GWMA

GWMA	No. samples	EC (µS/cm) min	max	average	
(023) Mis. Alluvium of Barwon Region	2	1130	1870	1500	
(063) GAB Alluvial	1	1420	1420	1420	
(601) Great Artesian Basin	5	64	954	488	
(604) Gunnedah Basin	9	594	4200	1905	
(608) Oxley Basin	2	1140	1220	1180	
(805) New England Fold Belt	6	798	2250	1180	
(814) Liverpool Ranges Basalt	2	889	2310	1600	
(819) Peel Valley Fractured Rock	4	548	1880	1025	
	31				

Target Groundwater Monitoring Bores

January, March, July 2009



Draft results – Monitoring Bores

- January, March and July 2009 samples collected by WRL
- Includes both shallow and deep monitoring bores in alluvial aquifers
- Analysis of pH, temperature and major ion data is in progress for each depth/aquifer
- Looking at both salinity (EC, TDS) and sodicity (SAR index)

GMU	No. Samples	EC (µS/cm) Min	Max	Average
(001) Lower Namoi Alluvial	63	272	26500	2432
(004) Upper Namoi Alluvium - Zone 2	17	879	5895	3129
(004) Upper Namoi Alluvium - Zone 3	26	736	19000	3599
(004) Upper Namoi Alluvium - Zone 4	27	283	1850	731
(004) Upper Namoi Alluvium - Zone 5	18	442	769	593
(004) Upper Namoi Alluvium - Zone 6	11	818	9694	3419
(004) Upper Namoi Alluvium - Zone 8	8	946	1117	1056
(004) Upper Namoi Alluvium - Zone 9	7	690	1380	1012
(004) Upper Namoi Alluvium - Zone 12	4	737	1512	1117
(005) Peel Valley Alluvium	12	363	646	483
	193			

Comparing data

Q: Are monitoring bore results similar to grower results?

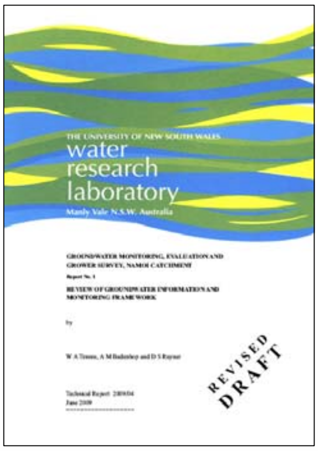
- ***Often relatively similar*** results for grower samples and monitoring bores sampled by WRL eg. Zone 4 Upper Namoi (7 grower samples)
- ***Sometimes a big difference*** between grower samples and monitoring bores samples. Grower samples probably not showing highly saline shallow groundwater. Eg. Zone 3 upper Namoi (3 grower samples)
- Some of the Grower samples locations are approximations based on the postal address, depth of sampling is often unknown
- Zones with 3 or less grower samples cannot be assumed to represent aquifer variability

Project status

Check for updates & reports here:

www.cottoncrc.org.au

www.wrl.unsw.edu.au/namoi



- 12 month project, budget of $370,000
- Regular progress updates to Cotton CRC & Namoi CMA
- Report No. 1
- Report No. 2
- CD-ROM with database

How to set targets for groundwater ?

Surface water targets for Namoi (NCAP, 2007)
500 µS/cm at Goangra 50% of time
1000 µS/cm at Goangra <80% of time

Challenge of setting targets for groundwater – a lot of variability

eg. shallow aquifers can be highly saline, deep alluvial aquifers fresh

Target
- relative change say 10% or 20% change
- to initiate further sampling and/or investigation

If target is too high eg. 10,000 µS/cm
- Insufficient warning of changes

If target is too low eg. 100 µS/cm
- Unachievable
- “Trigger happy” - lots of exceedences

Project team acknowledgements

The project team, led by Dr Wendy Timms, is working in partnership with Ingrid Roth and her team from GHD-Hassall who will undertake the grower survey.

WRL Projects team – Duncan Rayner, Alexandra Badenhop and Sara Mehrabi

UNSW Connected Waters Initiative is providing expert review (Assoc/Professor Bryce Kelly) and advice on spatial data analysis (Dr Bea Giambastiani).

Key team members have been working with the Namoi agricultural community for over 15 years, and also bring a wealth of international consulting and research experience.

Ground Water + @ UNSW

Consulting Projects:

Bill Peirson (WRL Director)
Brett Miller (WRL Manager)
James Carley
Dr Wendy Timms
Dr William Glamore
Steve Wyllie
Alexandra Badenhop, Sara Mehrabi
Duncan Rayner, Conrad Wasko
Hamish Studholme
& support staff

- Full time, dedicated project engineers providing expert services to industry & government
- Over 70 projects a year - locally & internationally
- Quality managed for certification AS/NZS ISO9001:2000

Business areas
Groundwater, Coasts & Estuaries, Environmental Data, Environmental Modelling, Water Resources, Civil Engineering Hydraulics

Research Programs:

Professor Ian Acworth
Assoc/Prof Bryce Kelly
Dr Ian Turner
Dr Martin Andersen
Dr Beatrice Giambastiani
Andrew McCallum
Anna Greve
Hamish Studholme
& support staff

National Centre for Groundwater Research and Training (NCGRT)

Connected Waters Initiative
Funded by Gary Johnston
UNSW Faculty of Science
UNSW Faculty of Engineering
Research Grants
Cotton Catchment Communities CRC

Collaborative Links
Centre for Water and Wastewater UNSW
US Army Corp of Engineers

PART B:

GROWER SURVEY

GHD CLIENTS | PEOPLE | PERFORMANCE

GHD Hassall

Cotton CRC and Namoi CMA

Report for

Namoi Groundwater Monitoring - Groundwater User Survey

In Conjunction with UNSW Water Research Laboratory

Final Report

October 2009

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

Executive Summary

A survey and workshop series involving groundwater users in the Namoi was undertaken to seek to identify the potential to improve collection and communication of groundwater monitoring information and interest from groundwater users in participating in a community monitoring program.

Key findings were:

- Most groundwater users have a good to reasonable understanding of groundwater issues but limited knowledge of the current condition of the resource.
- Groundwater users would like to receive more regular (annually and when critical changes are detected is sufficient for most) information about groundwater condition, preferably before the start of each irrigation season.
- Some information is readily available but not all groundwater users are aware of this, many have not tried to find it.
- Many were happy with how they had received information in the past (status reports and meetings) but felt that this service had deteriorated in recent years with cut backs in the department and loss of hydrogeologists.
- Some would like to see real-time data. The telemetry program which is being set-up now was expected to help achieve this.
- Other than a few specific areas, water quality is generally considered to be good and there is more interest in groundwater levels than in quality.
- Many groundwater users informally monitor their groundwater bores but few maintain records over time.
- There is willingness but many reservations (including concerns about how data will be used and reliability of the data) and not great enthusiasm for a groundwater user monitoring program. There are some exceptions to this and in some localities a monitoring program may be more successful.
- Sampling by groundwater users will be more favourable if undertaken during the pumping season – the first pumping of the season (August/September) and the last (February / March) were suggested as suitable times for sampling.
- Providing and promoting a standard protocol for on-farm monitoring and data recording was suggested to enable comparison between groundwater users.

There is significant scope and demand for improving the communication of information about groundwater condition in the Namoi. The new telemetry program will go some way to help this but is not the complete solution as it will only provide information about levels (not quality), does not provide any interpretation of trends and is limited to a relatively small number of bores.

Recommendations are:

1. Work with the NSW Office of Water to develop an approach to enhance their program of groundwater monitoring and communication in the Namoi, including potential enhancements to the new telemetry program.
2. Develop and promote protocols for groundwater users to gather and track their own groundwater data and encourage discussion of findings.
3. Improve communication and promotion of data about groundwater monitoring, using a combination of methods to distribute information at least annually before water use decisions are made for the summer season. This would include distribution of status reports, a series of winter meetings for interpretation and discussion and real time information from monitoring bores available via the internet.
4. Supplement the NSW Office of Water data by supporting additional independent monitoring, particularly a periodic program of groundwater quality analysis.
5. Further investigate the benefits, costs and implementation options of a coordinated monitoring program that would involve:
   - Sampling at the start and potentially also the end of the summer irrigation season (ie August/September and February/March);
   - Standard, robust, easy to follow methodology for sampling procedures;
   - Quality checking;
   - Centralised analysis and interpretation;
   - Rapid feedback on individual analysis and interpretation of results across region/zone (within 2 months);
   - Comparison of findings with NOW data sets;
   - Confidentiality of data;
   - Recognition of the limitations and ownership of the data; and
   - Funding of coordination and monitoring equipment.

Contents

Appendices

1. Introduction

1.1 Purpose

GHD Hassall in conjunction with the University of New South Wales Water Research Laboratory (UNSW WRL) have undertaken work to investigate groundwater monitoring and grower participation in the Namoi Catchment.

This project, commissioned by the Cotton Catchment Communities Cooperative Research Centre (Cotton CRC) and the Namoi Catchment Management Authority (Namoi CMA) aimed to build on the Namoi CMA State Monitoring and Evaluation Programme, the current NSW Office of Water (NOW, formerly DWE) monitoring programmes, and any relevant data generated by the Cotton CRC. The aims of the project were:

- Establish a framework for benchmarking groundwater quantity and quality in the Namoi which will form the basis of future assessment.
- Understand how the condition of the catchment varies over time and across the region and to utilise this information to improve the management of groundwater resources in the Namoi.
- Complete a social component to understand what information groundwater users are seeking, their existing knowledge about groundwater and their willingness to participate in a coordinated monitoring program.

UNSW WRL led the project and undertook the majority of the work including monitoring, data analysis and analysis of grower samples whilst GHD Hassall undertook the grower survey and facilitated the workshops.

1.2 This Report

This report presents the findings from the groundwater user survey and workshops and makes recommendations for future involvement of groundwater users.

2. Consultation Process

The steps followed in undertaking the grower survey were:

1. **Project initiation meeting**

   A project initiation meeting was held in Tamworth with the Cotton CRC, Namoi CMA and UNSW WRL to confirm the scope of the project. This was followed by:

2. **Consultation meeting with key industry representatives**

   Namoi Water, Cotton Australia, NSW Farmers and the Office of Water (then DWE) participated in a meeting in Tamworth and gave support to the project.

3. **Identification of key research questions**

   Drawing from the terms of reference and discussions, key research questions were drafted and further refined through teleconferences with UNSW WRL, Cotton CRC and Namoi CMA.

4. **Written survey form**

   A number of questions were included on the 'Groundwater Sampling in July' form. This form was completed by groundwater users who submitted a sample for testing. It provided an additional data set with perspectives from the 76 individuals who had chosen to submit a sample for analysis. The distribution of these responses is illustrated in Table 1. (Appendix B1)

Table 1 Distribution of interviewees

Groundwater Monitoring Area		**Total Samples**
Great Artesian Basin Alluvial		3
Great Artesian Basin		5
Gunnedah Basin		12
Liverpool Ranges Basalt		2
Lower Namoi Alluvium		18
Miscellaneous Alluvium of Barwon Region		2
New England Fold Belt		7
Oxley Basin		2
Peel Valley Fractured Rock		4
Upper Namoi Alluvium	*(Total)*	*(22)*
	Zone 2	3
	Zone 3	3
	Zone 4	7
	Zone 5	2
	Zone 6	2
	Zone 7	1
	Zone 8	3
	Zone 11	1
Total Samples Received		**77**

5. Telephone interviews

a. Scoping interviews with key informants

A small number of scoping interviews were conducted with key informants including Namoi Water and growers and a consultant who are active in the water / research arena.

These interviews were open ended and supplemented by informal discussions with other stakeholders. They gathered a broad insight to inform the development of the survey questions.

b. Development of survey guide

A written survey guide was developed and these questions reviewed by UNSW WRL, Cotton CRC and Namoi CMA. (Appendix B1)

c. Compiling contacts list

Namoi Water provided a randomly selected list of names of 90 groundwater users. Unfortunately there were no phone numbers included and numbers for approximately half of these names/businesses could not be found. Namoi CMA then provided a list of people who had expressed interest in water use efficiency programs. GHD Hassall supplemented these lists with names of groundwater users known to us.

d. Interviews

Telephone interviews were conducted with 66 groundwater users over the period mid July – August 2009. Those interviewed were from across the Namoi Catchment (Table 2) and included irrigators and non-irrigators.

Most people contacted were very willing to participate. Eight people declined to be interviewed while a further 18 asked to be called later and then couldn't be contacted.

After approximately half of the interviews had been undertaken, the interview team debriefed to determined if there were emerging themes to pursue and adapt the interview questions for remaining interviews. Whilst there were some strong themes emerging, there was also quite some variability in responses and thus it was decided to continue with the same set of interview questions.

A few final interviews with key informants (NSW Office of Water, lead grower, Liverpool Plains Land Management Committee), explored the emerging findings.

Analysed results are presented in this report and detailed responses to some questions are presented as Appendix B2.

Table 2 Distribution of interviewees

Location	No. of Interviews
Tamworth	4
Kootingal	2
Hallsville	1
Manilla	3
Dungowan	2
Attunga	1
Quirindi	7
Werris Creek	1
Willow Tree	1
Blackville	1
Gunnedah	9
Breeza	2
Emerald Hill	1
Mullaley	2
Tambar Springs	3
Carroll	1

Location	No. of Interviews
Boggabri	7
Maules Creek	1
Harparary	1
Narrabri	7
Wee Waa	5
Merah North	3
Pilliga	1

6. Workshops

Three workshops were held to present findings of the project and to gain groundwater users' feedback on suggested future directions in groundwater monitoring. These workshops were held jointly with Namoi Water's AGMs as follows:

- Zone 3 – 4pm, Monday 31st August, Gunnedah
- Lower Namoi – 8am, Tuesday 1st September, Wee Waa
- Upper Namoi – 3pm, Tuesday 1st September, Gunnedah.

The workshop agenda and notes are included as Appendix B3.

3. Findings

3.1 Knowledge about Groundwater Levels and Quality

The majority of groundwater users we spoke with had a reasonable to very good understanding of groundwater issues. The scale of knowledge varied, with some very knowledgeable about groundwater issues in general and across the zone, through to others whose knowledge was more about their own bores. A few people who had small blocks or were new to the area had very little knowledge about groundwater.

Generally people understood about groundwater systems and monitoring but they had limited access to data and so were not aware of the current condition of the resource. Many commented that they would like to know more about the groundwater condition.

There was a lot of interest and questions about the connectedness of ground and surface water systems.

"The whole system is interconnected. Very seasonal. Creeks are recharge, run a lot less now. Creeks no longer have permanent water whereas they used to be permanent or at least most of year. It must be linked to the pumping downstream of bores right beside the river." Stock and Domestic, Maules Creek

There was interest in knowing more about the groundwater system as a whole including:

- Connectivity between river and bore systems;
- Recharge to the aquifer;
- Potential impact of mining on the aquifer; and
- Long term changes vs seasonal variability.

3.1.1 Groundwater levels

The majority of groundwater users felt that groundwater levels had dropped over the longer term (eg 30 years).

"Levels have changed dramatically over time. There has been huge drawdown. When I first pumped in 1976, standing water level was 22m now its getting over 70m." Irrigator, Spring Plains

Many commented that there was a lot of seasonal variability. A few commented that levels in their area had improved and this was felt to be a response to the cutbacks in use.

There was a lot of interest in the recharge to the aquifer and the longer term balance of the groundwater system.

"Groundwater levels are depleting, they were at 38ft 33 years ago now at 75ft today. They used to say we'd get one flood every 5 years. In our first 5 years we had 5 floods. We have barely had 3 or 4 flows in the past 10 years. However the recharge in this area is good. They can get 18mm not far from here and by the time it gets here its all in the aquifer. Pumping is one factor and the other is not getting the rainfall for the recharge." Irrigator, Stock & Domestic, Quirindi

There were many comments about the drawdown effect of pumping and the immediate and longer term effects of this.

"Our well is 350m from the river - if our neighbours irrigate, you quickly notice the difference in groundwater levels. Same thing if the river stops flowing." Lucerne Irrigator, Tamworth

Usage rates, drought and the features of each aquifer (eg shallow system, linked with river, rainfall, underground streams) were thought to have contributed to declining water levels. Interestingly, one person commented that they had monitored groundwater levels during 10 years of drought and not seen a change in levels.

"I've been on the property for 20 years, there was a permanently flowing creek that flowed for 15 years now it has stopped and the ground water levels have dropped over the last 5 years. I thinks it's a climate change thing." Grain irrigator, Stock & domestic, Boggabri

Close to Tamworth there was comment on the effect of subdivisions.

"A lot of our water comes from Moore Creek catchment. It used to run nine months of the year. Now it runs two weeks of the year. Subdivision has put pressure on the underground water supplies. There are lots of small acreages now." Lucerne irrigator, Tamworth

In-season variability was seen to be quite different from longer term trends as the aquifer was thought to recover at least to some degree between irrigation seasons. However, there was thought to be a lack of data to know what the longer term trends are.

"I wish I could tell you more about the groundwater condition – but I haven't seen the data to be able to know for a few years. We need the data to be able to tell whether the water sharing plan is working." Cotton Irrigator, Narrabri

There was a genuine interest from many in knowing more about the groundwater condition so as to be able to manage the resource more sustainably.

"I'm the last person to want to pump more than the groundwater system can handle, we need better, timely information to make these decisions." Cotton and grain irrigator, Narrabri

3.1.2 Groundwater quality

Most people had not detected a decline in water quality, with quality generally thought to be very good. That said, most had not tested water quality or at least not since the original test done when the bore was sunk.

Some noted that in dry spells the water quality changed temporarily. For example, it was becoming 'harder'.

"Used to be able to see it [poor water quality] *in the vegetables - tended to be correlated with reduced groundwater levels/flows." Irrigator, Tamworth*

Generally there was less interested in quality than in levels, unless there was a known groundwater quality issue. There was more discussion in the Lower Namoi workshop that elsewhere about water quality, some farms in that area have concerns with the quality of water from their bores.

Some groundwater users, particularly those who rely solely on groundwater for their water supplies, have limited options in relation to quality.

"Crop yields are down because of the water but I've stopped monitoring the quality as I don't have any other options at the moment. If I had spare water on our other farm I'd transfer that here to mix with the groundwater." Cotton Irrigator, Merah North

3.2 Views about Groundwater Monitoring

Most people felt it was important to monitor groundwater condition for a range of reasons, including:

- To know whether the aquifer is recovering and so be able to manage it sustainably;
- To know whether the quality of the water is suitable for crops and won't degrade the soil;
- To monitor impacts of mining.

There was interest in both quality and quantity, with most interest being in relation to groundwater levels.

A very small number felt there was no benefit in monitoring groundwater. Some were concerned that the only outcome of monitoring would be further cut backs in water allocations.

When asked whether there was currently enough monitoring underway, people varied. Roughly equally portions of respondents felt there was enough monitoring, not enough or were unsure. Many (including several of those who felt there was enough monitoring) were unclear as to how often monitoring was done and had not seen that data for some time.

There was wide awareness of the network of monitoring bores and that the department was responsible for monitoring these. Most people were unsure as to how often this monitoring occurred.

There was some concern as to whether the current network of bores was suitably representative of the changes seen on farm – particularly where the monitoring bores were in stockroutes close to the river and the irrigation bores were a long distance away.

More detailed comments are included in Appendix B2.

3.3 Data Accessibility and Communication

3.3.1 Groundwater information from the NSW Office of Water

NOW indicated that groundwater information is available through the following channels:

1. From the internet:
    a. Usage data indicating what water been pumped and traded;
    b. Telemetry of 30 bores to be presented as hydrographs will become available within the next 12 months;

   c. Groundwater bore map, construction details and geological logs – NSW Groundwater Works www.waterinfo.nsw.gov.au/gw/

2. Status reports – NOW are still committed to these but due to a lack of staff, these reports are being completed and released on a zone by zone basis when possible; and
3. Information can be obtained at any time through submission of a ‘data request’.

A community monitoring program is currently under trial in the Lachlan region. This data is unlikely to be included in NOW’s data sets but would be valuable additional data for status reports.

NOW’s program monitors groundwater levels. There is no regular program for monitoring groundwater quality.

3.3.2 Perceptions about current data availability

There was quite some variation about the perceived accessibility of information about groundwater condition (Figure 1). Most people indicated that they hadn’t tried to source information.

“We used to get it but haven’t seen anything for a few years….” was a common response about the availability of data about groundwater monitoring. The information provided in the past by the department was really valued. In particular the status reports, workshops and the open relationship many had with the local hydrogeologists.

Some felt it was easy to get information – these people were primarily in the upper area of the catchment. A Lower Namoi grower noted that if they went into the department they could easily get the information they wanted.

“It’s just a phone call away.” Irrigator, Stock and Domestic, Werris Creek

Some people gained the test results from monitoring bores near them because when they saw the departmental officer monitoring they approached them directly to ask what the reading was.

There was a widely held feeling that the department was under-resourced and no longer had enough hydrogeologists to do the job. While this was often understood as part of general cut back of government services, there was also frustration that groundwater users are paying for this monitoring service that is not being done, or at least they are not seeing the results of.

“Licence fees are high and should be used by the department to do independent, scientifically rigorous monitoring to maintain the asset.” Irrigator, Gunnedah

Many had not actively searched for information about groundwater quality and some didn’t know where to look for the information if it was available.

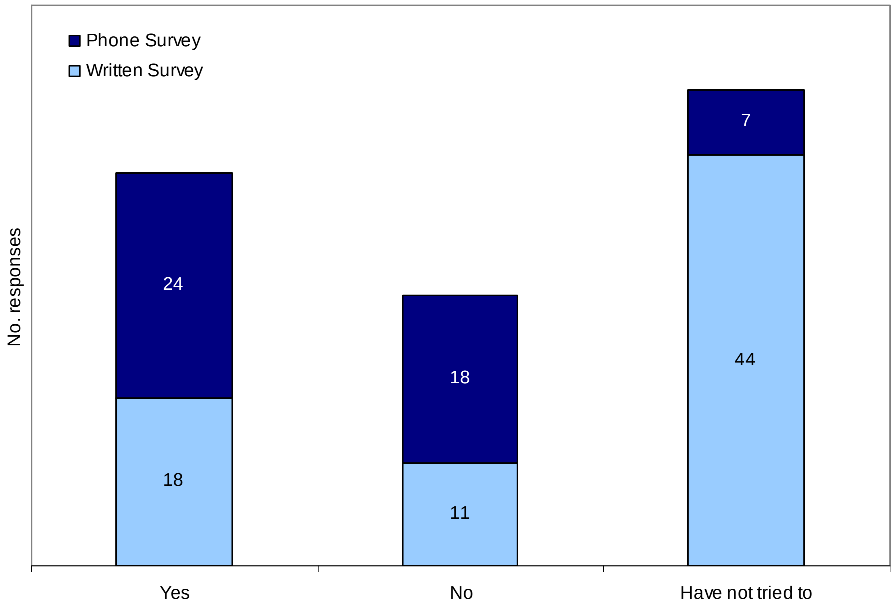
“Don’t know where to look.”

“There is information available at meeting but those are an irrigators’ thing.” Stock and Domestic, Maules Creek

Some people felt that the information about the groundwater system must exist, but is not be being made available.

"We've hit a blank wall trying to get data from monitoring bores – the department say it's not available but we know they are using it for their own purposes." Irrigator, Tamworth

Figure 1: Can you readily access information about groundwater condition?



3.3.3 Preferred modes of information dissemination

There was a high degree of variation in the preferred modes of seeking information (Table 3, Figure 2) which may indicate that one mode will not be very effective in reaching all groundwater users. Most people prefer to have more than one way of receiving the information (eg status reports and winter meetings).

One respondent indicated that no change is needed as the data is readily available whilst many were keen to see a return to annual information flow.

"A status report + winter meeting for interpretation as had been done in the past. Also make data available on the web." Cotton Irrigator, Narrabri

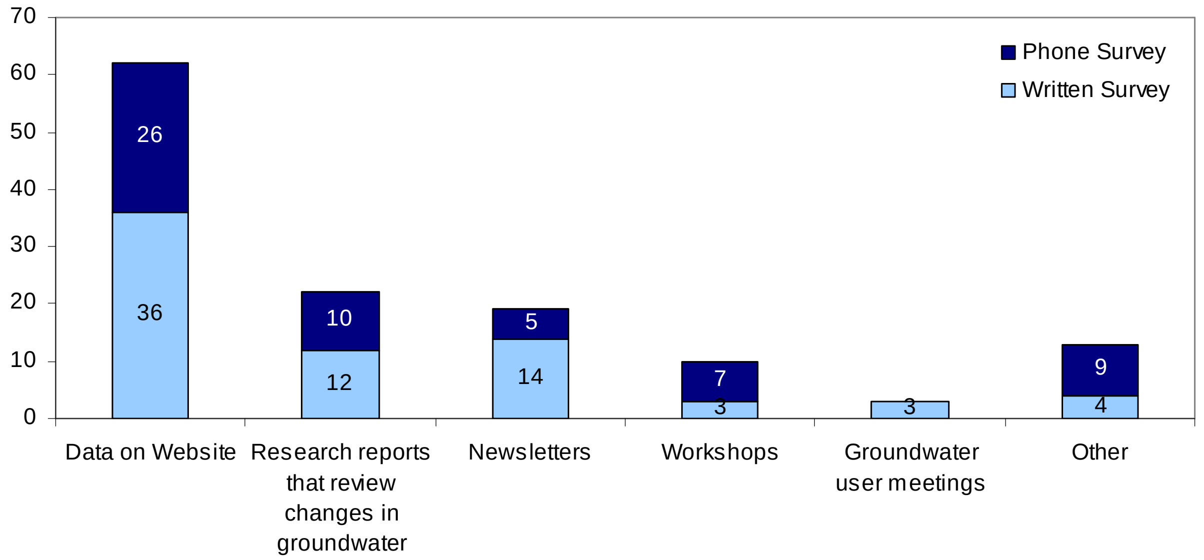
"Regular meetings in a local areas where a hydrologist should show graphs of the last twelve months compared with the previous 12 months. There should also be data from 30-40 test holes and records of pumping, and records based on meter readings." Lucerne & Pasture Irrigator, Stock, Quirindi

"We want accurate data - however we can get it - Web access to live data, hydrographs; this would be most cost effective and save need for roadshows. Have volumetric monitoring on a sample of the bores so we can dial in to see data – would need all 3 levels of aquifers. It is high cost but irrigators are paying a fortune in licence fees." Irrigator, Breeza

Table 3: Preferred ways of receiving information

Promotion and communication about how or where to get the information that's collected.
Status reports
Published and circulated within catchments
Newsletter, flyers, emails
Website – with reports and live data / hydrographs
Make a sample of bores volumetric so can dial in to see data - need all 3 levels of aquifers.
Maps
Graphs
Mail, email or fax
Seminars, presentations in winter (June-July) September is a bit late.
Regular meetings in local areas where a hydrologist should show graphs of the last twelve months compared with the previous 12 months. There should also be data from 30-40 test holes and records of pumping, and records based on meter readings.
Local landcare groups
Distribute information from test bores to surrounding licence holders

Figure 2: How should information from a coordinated monitoring program be communicated?



3.3.4 Frequency and timing of information distribution

The majority of respondents wanted information to be made available annually and when any critical changes are detected (Figure 3). Some would like it more often (6 monthly, quarterly, monthly). A portion of respondents felt information should be accessible as soon as it is available. Comment was made that the system is slow to respond and therefore there is no real benefit to have information too often.

"Quarterly or annually. Groundwater reacts slowly." Cotton Irrigator, Spring Plains

Suitable timing of information flow was seen to be very important. Most wish to have up to date information before the start of each season or at least before decisions are being made for the summer season.

"No more than 6 months. Once at beginning at start of irrigation in August/September and once at finish in February/March." Irrigated pasture and Stock, Quirindi

There are also differences depending on the type and use of the data:

- Long term trends – sought once or twice/year, pre-season
- Data for in-season management – real time or very quick.

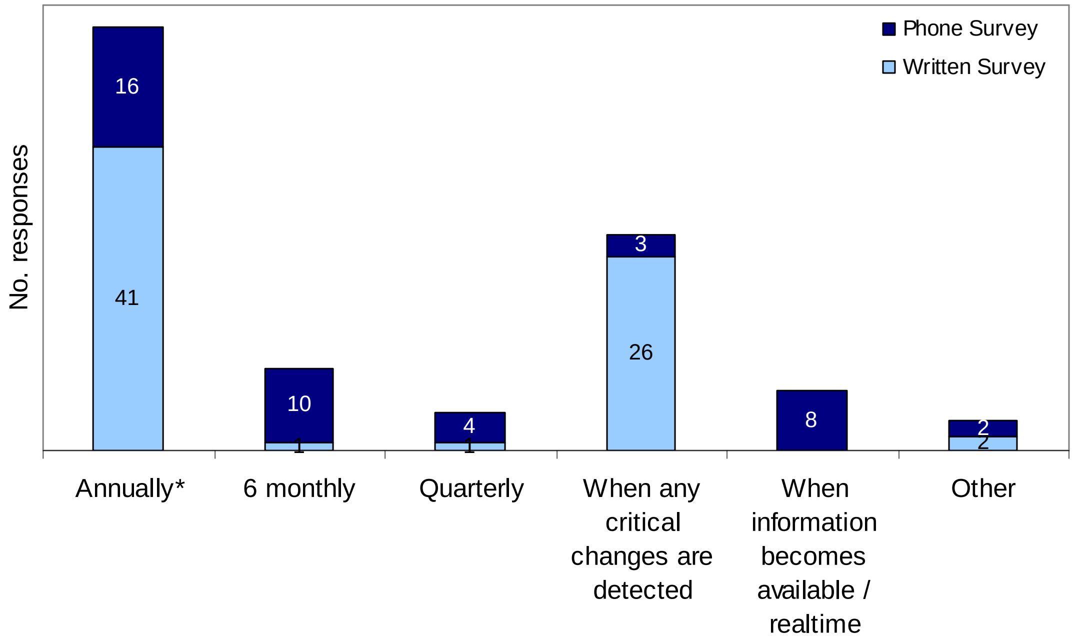
"Realtime for in season; annually for status report" Cotton & grain irrigator, Narrabri

Most people are interested in the long term trends – they want to know what this is before the irrigation season starts as once they have made planting decisions there are limited opportunities to alter water use patterns. A few are interested in better data for management decisions during the season (eg which bores to use when, when to switch between river and groundwater for benefit of groundwater system).

There was some interest in seeing quality data more frequently than the information about levels.

"Pre-season for levels. Quality data in season." Cotton & grain irrigator, Wee Waa

Figure 3: How frequently should groundwater monitoring information be made available?



NB The response options for the written survey were "Annual", "When any critical changes are detected" and "other" – which may have influenced the lower responses in other categories.

* 11 of those who responded "annually" in the written survey also suggested "when any critical changes are detected" – perhaps indicating annual as a standard with additional information if critical change are detected.

Several people indicated more than one option (eg annually or quarterly) or noted "before the season" or "before and after the season".

Other included "monthly", "every 5 years" and "we need more training on interpretation of water quality tests"

3.4 Current Monitoring by Groundwater Users

There is a lot of informal monitoring carried out (eg pump rates, occasional checking). There is limited recording and tracking over time of any changes in groundwater.

While most people indicated that they do currently monitor groundwater (Figure 4 indicates that 60% of the phone interviewees currently monitor their bore), most of this is not done rigorously.

Some people have regular analyses done of water samples from their farms. However even though most would keep the analysis results there are only a few who do track the results over time.

A few groundwater users (four of the 66 interviewees) have kept collated records of water quality and/or levels over time. This includes a 40 year data set of bore water quality, with analysis each year being undertaken on different bores such that each bore is analysed every 3 years (in rotation). Another farm has a 10 year data set of weekly monitoring of groundwater levels.

Figure 4 Do you currently monitor your bore?

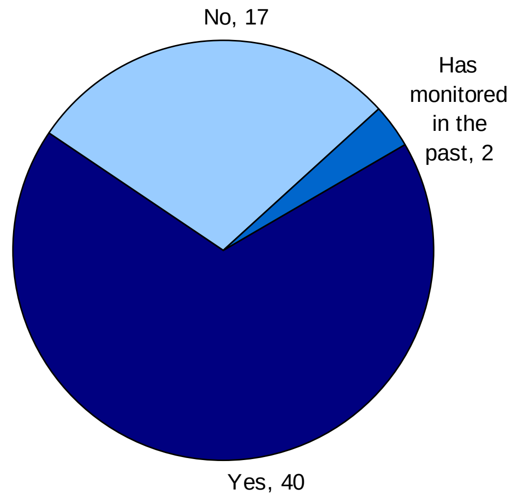
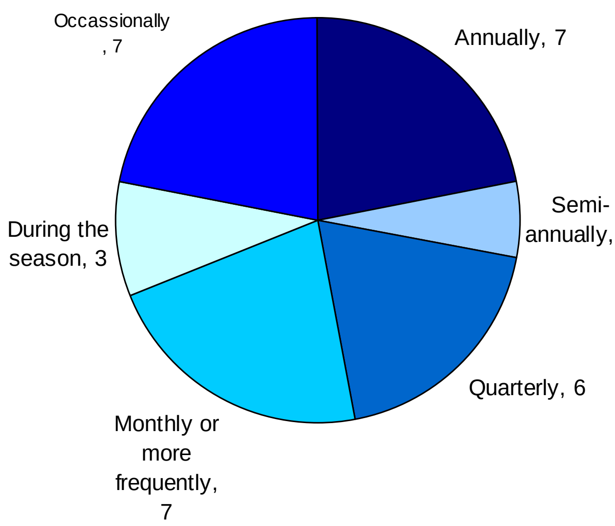


Figure 5 How often is monitoring done?



NB responses from phone survey only

3.5 Views About a Coordinated Monitoring Program

A detailed list of comments relating to participation in a coordinated monitoring program is provided in Appendix B2. There were considered to be real benefits in groundwater users undertaking monitoring:

- To get more data
- To have an independent data set
- Users see what's happening all the time *"The farmers are the ones at the wells, therefore they'll notice the biggest differences."*

Most people indicated that they saw value in a coordinated monitoring program (Figure 6), were willing to participate (Figure 7) and considered it important to gain additional information about the groundwater condition. Of those who responded that they may be willing to contribute data some indicated they would be more willing if their data was treated anonymously or once they knew what was involved. Others were concerned that if the water was of poor quality then they needed to know themselves but wouldn't want others to know. Those who had sent in samples for the "Groundwater in July" monitoring (written survey respondents), indicated in fairly similar proportions that they would be willing to monitor annually, quarterly or as often as required (Figure 8).

"The more information available, the better decisions that can be made."

Figure 6: Do you see value in landholders contributing their monitoring data to a coordinated program?

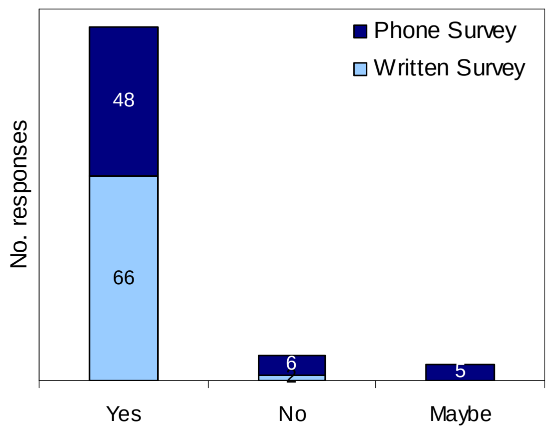


Figure 7: Would you be willing to participate in a coordinated program?

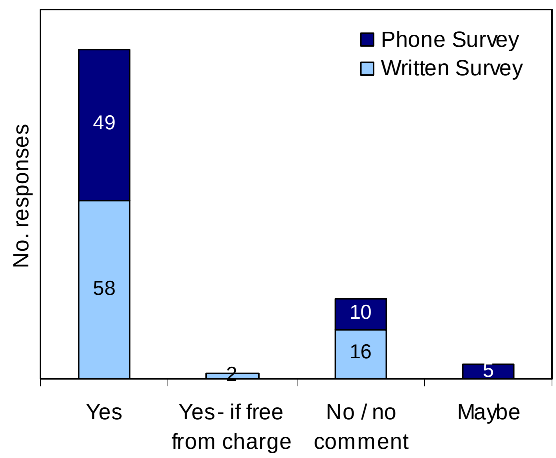
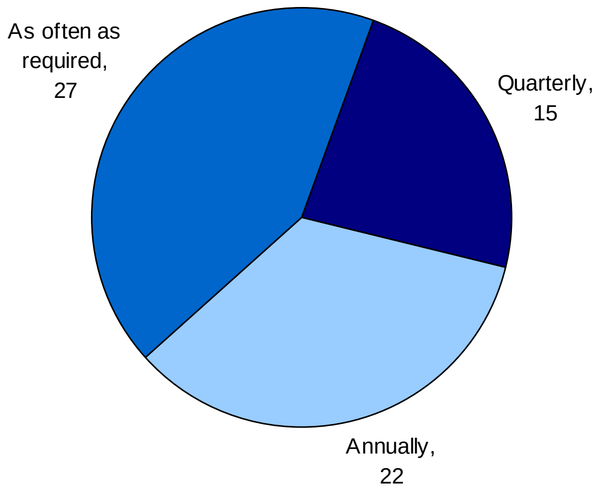


Figure 8: How often would you be willing to monitor?



NB responses are from written survey only

Despite the high level of support and stated willingness to participate, there did not appear to be a high degree of enthusiasm and there were many reservations about a user monitoring program. The main concerns related to:

- Reliability of the data (real and perceived) *"Risky - don't know how the data has been taken - credibility and accuracy is questionable." "It won't work if people were fudging results for their own means or if people do not participate."*
- Whether enough people would supply accurate samples "*Worthwhile if everyone did it regularly - but would they?"*
- How the data would be used and who it goes to. *"Don't trust what would be done with the data"*
- How the data is presented – and whether this is suitable to the quality of the data.
- Practicalities and timeliness of sampling and testing
- Cost – of analysis and power cost to pump out of season (up to $800) *"Users shouldn't have to pay for the monitoring service and also do that service."*
- Is there a need for it? *"We should have enough data from monitoring bores"*
- Having the time to sample, and remembering to do it. *"Time, people don't get round to it, too busy with other things."*
- Lack of feedback *"Haven't had feedback from involvement in previous monitoring projects"*
- Risk of losing more water allocations *"We don't want the water issue stirred up anymore, monitoring is only likely to lead to more cutbacks, not water allocated back."*

"We need a reliable, rigorous pool of data and grower data is not enough." Irrigator, Tambar Springs

Counteracting the concerns, most people were willing to participate and felt it would be worthwhile if there were enough contributors.

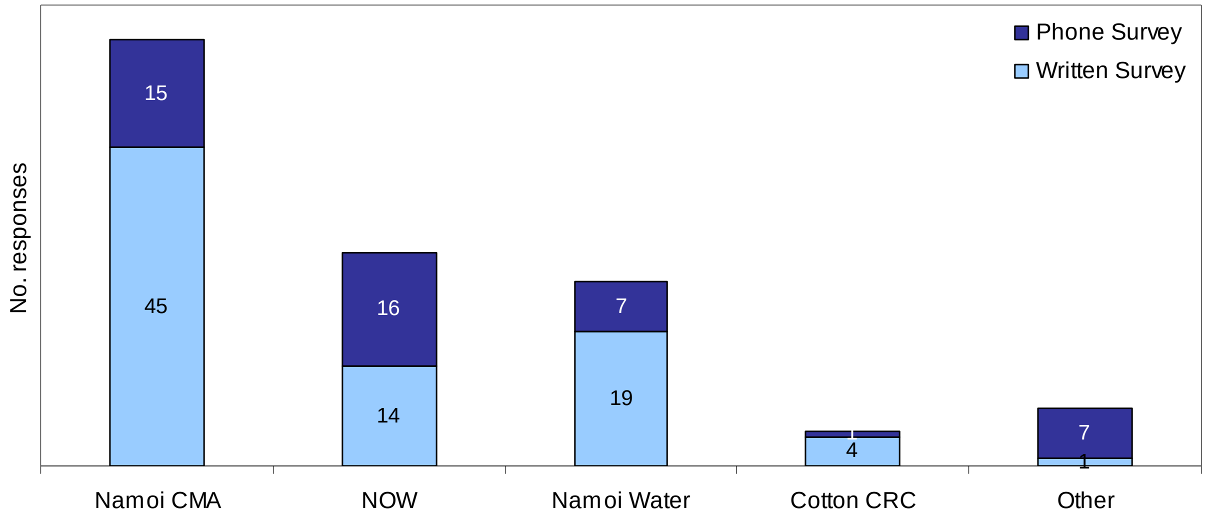
Some people were very concerned about who would obtain the data from a coordinated monitoring program. In particular some would prefer that the department (NOW) did not receive the information, mainly as they were concerned that the data may be used against them. Conversely, many were not particularly concerned who had the data and others suggested that the department (NOW) would be most appropriate organisation to coordinate the data as they had the other existing data sets and could compare them.

Figure 9 indicates that the majority prefer that the Namoi CMA coordinate monitoring by groundwater users, followed by suggestions for NSW Office of Water or Namoi Water. It was noted that resourcing would be required for Namoi Water to be able to take on the coordination role. John Clements has suggested that he does not think it most appropriate for Namoi Water to be the coordinators. David Walker from the Liverpool Plains Land Management Committee indicated that, with resourcing, their organisation would be happy to coordinate a monitoring program.

Expected longevity of the organisation was a factor noted when considering who would be most suitable. Some considered the Cotton CRC but did not suggest them as suitable as the organisation may not continue into the future.

"There is value in a coordinated monitoring program but data can be deceiving and pumping activities by neighbours can add noise to the data set which may be misleading. Data should be owned and coordinated by a grower funded group and not provided to departments/agencies as this may lead to a reduction in pumping hours." Irrigator, Gunnedah

Figure 9: Who should coordinate a community monitoring program?



Other included: NSW Farmers, Cotton Australia, Irrigation industry, Peel Valley Water, Private firm, Grower funded body, Independent body, Not concerned who.

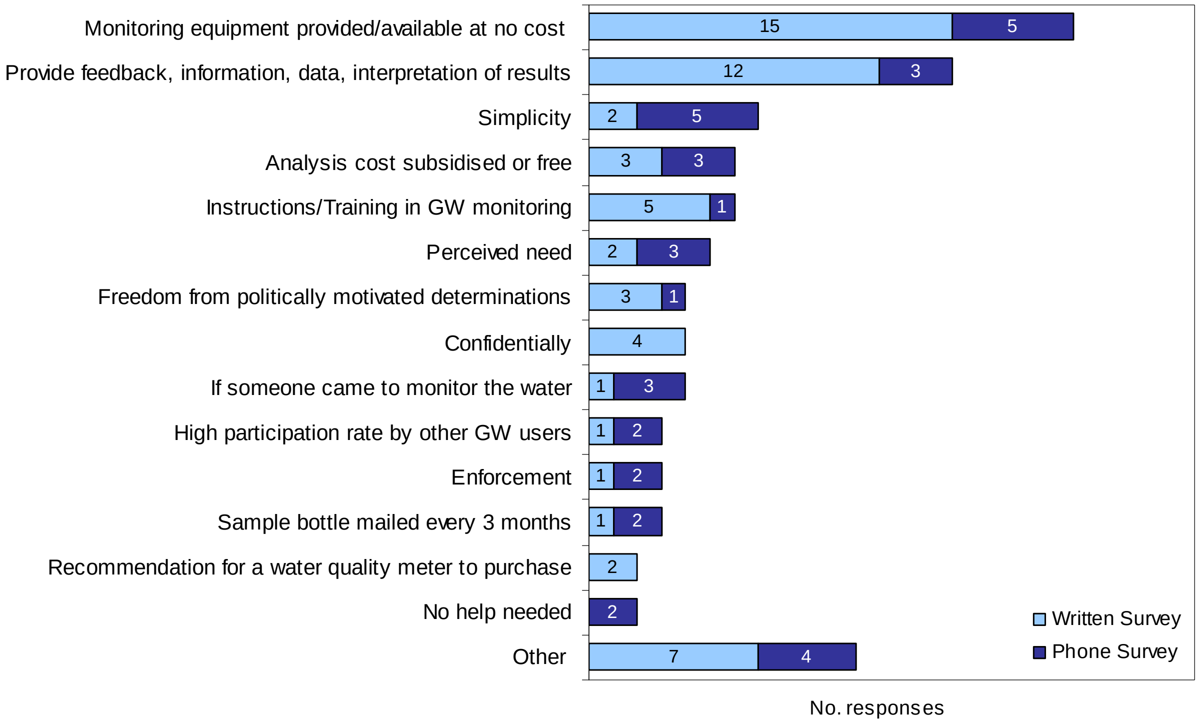
NB some suggested more than one group to be suitable.

3.5.1 Enablers

Groundwater users were asked what things may help them to participate in a groundwater monitoring program. Suggestions are illustrated in Figure 10. Whilst some of these things are hard to influence (eg more time), many can be considered in design of a coordinated program.

Providing equipment and analysis at no or a subsidised cost was the most common suggestion. Feedback about data was also important. In fact, some people were reluctant to participate because they had contributed samples to programs in the past and not seen the results or because they were concerned about where the information would go.

Figure 10: What would assist you to participate in groundwater monitoring and share your data?



“Other” included: Automation; Local CMA availability; Regular checking; Any bit of help would be good, to make sure the monitoring is done regularly; Workshops - working and meeting with other farmers; If I was asked to increased monitoring; Knowing about monitoring programmes; Time - if had the time would happily contribute; The same program run say every 5-10 years (ie no charge to participants); Honesty.

3.6 Other suggestions for groundwater monitoring

Groundwater users made a number of suggestions about gathering and communicating information about groundwater condition in the Namoi which have been described above.

Another suggestion was to established a set of “Sentinel bores”. Recognising the time taken to monitor all bores regularly, suggestion was made to select a representative sample of bores which could be monitored more frequently and readings rapidly communicated to groundwater users. It was suggested that in some areas this would need to include some on-farm bores which may be more representative than the current sample of monitoring bores.

Note: the current program of telemetry will provide real-time information on a sample of monitoring bores.

3.7 Common questions about groundwater monitoring

During the interviews, a series of questions arose which have been collated below with brief responses:

1. I'm more interested in groundwater levels than quality - how would monitoring quality help me?
    - ➢ Quality can be an indictor of a change in the system; So you know that the quality of water is suitable for usage for drinking, irrigation or stock.
2. We don't pump in July - why did you have the sampling then?
    - ➢ Scientifically it is the best time to sample as groundwater levels and quality are stable at this time.
3. Our groundwater quality hasn't changed over the last 5 years - why keep on monitoring?
    - ➢ It is important to get a sample every one or two years as it may remain constant then can change. Also important to monitor in order to prove it hasn't changed.
4. How reliable is a grower monitoring program and what affects reliability?
    - ➢ It is important to know what the salinity is at point of use. The reliability of data sets will vary depending on how samples are collected. Reliability of scientific v grower samples will also vary.
5. How meaningful for management is in-season data compared to long term trends?
    - ➢ Long term trends will give a better indication of the aquifer condition.
6. I can't measure groundwater levels on my irrigation bore so I measure it on a domestic bore - is that a good enough indicator?
    - ➢ It will be if it is the same aquifer – but it may not be.
7. How long do I need to switch the pump off before measuring levels?
    - ➢ There is no easy answer as to how long to wait. Wait until the water level stabilises (anywhere from 15 min to 8 hours)
8. How much can my bore vary from the monitoring bore nearby?
    - ➢ Sometimes these are pretty similar and sometimes they are not. It may also depend how far away from the monitoring bores the irrigation bores are. Monitoring bores are designed to measure only one aquifer whereas irrigation bores can combine several aquifers at different depths.
9. How often are the monitoring bores checked?
    - ➢ In theory groundwater levels are checked every six weeks.
10. Is it possible to select a ‘representative sample of bores’?
    - ➢ This project and also the telemetry project is taking a scientific approach to selecting representative bores. There is a need to choose bores that are representative of highly fluctuating areas and areas at risk of change.

11. We really need to know more about the whole groundwater system - where the water comes from, how it's connected with the river, etc - what work is being done and where can we find out more?

    - More information about other projects is on the websites of
        - Cotton Catchment Communities CRC (www.cottoncrc.org.au)
        - UNSW WRL (www.wrl.unsw.edu.au/namoi)
        - UNSW Connected Waters Initiative (www.connectedwaters.unsw.edu.au)
        - CSIRO sustainable yields project http://www.csiro.au/partnerships/MDBSY.html
        - NSW Office of Water (http://www.water.nsw.gov.au/Water-Management/Water-availability/Groundwater/default.aspx) and
        - Australian Government (http://www.connectedwater.gov.au/).

4. Discussion of Findings

Findings of the surveys and workshops indicate that groundwater users are keen to have more information about the condition of the groundwater resource.

Whilst there is some variability, most have a broad understanding of groundwater issues and could be considered to be already ‘engaged’ users of this resource.

There is significant concern that the NSW government (now through the NSW Office of Water) have not maintained the communication of data about groundwater condition and possibly have not maintained the data sets.

There is some interest from groundwater users in a coordinated program of monitoring. Close to 70 samples were received for the “Groundwater in July” program which could be considered to be an acceptable participation rate considering that it was not building on any existing program. There were also many concerns about a future coordinated program of sampling by users. Such a program would not replace groundwater users’ requests for independent monitoring but it may potentially supplement it. It would be worthwhile encouraging individual groundwater users to monitor and keep good data sets for their own benefit. However, there are additional costs associated with a coordinated monitoring program and this does not appear to be the highest priority if funds are limited.

Rather, the highest priority appears to be the timely communication of data collected from monitoring bores. Telemetry of selected bores will go some extent to fill this need but will not replace the whole of valley monitoring and the interpretation of results.

This may be supplemented with additional data if desired / needed through a groundwater user program or independent data analysis.

4.1 Interim suggested options

Drawing on the survey findings, discussions with the projects team, Cotton CRC and Namoi CMA led to the development of the following set of options for future groundwater monitoring and communication. These were presented to the workshop groups for discussion (as recorded in Appendix B3).

1. Enhanced data gathering/ communication by the Department
2. Telemetry on a representative sample of bores – real time data available
3. Supplement with:
    a. additional independent data gathering from monitoring bores
    b. additional independent data gathering from grower pump bores
    c. coordinated program of monitoring by groundwater users of their pump bores
4. Groundwater users keep a log of own bores and seek advice if a significant variation occurs
5. Supplement with independent analysis/ communication
6. No change.

5. Preferred Options for Future Groundwater Monitoring and Communication

All workshop discussion groups agreed that it was important to improve the gathering and communication of information about the condition of the groundwater resource. However, there was not clear, unified agreement across the Namoi on which options are most preferred. Rather, it was concluded that different zones (and areas within zones) are likely to participate in different approaches for groundwater monitoring.

While groundwater users are keen to receive more information about groundwater condition this is a point of frustration for them rather than a high priority to pursue. Any future efforts to improve groundwater monitoring and communication will likely need to be driven by a group such as Namoi CMA, Cotton CRC or Namoi Water.

The workshop groups identified their preferred approaches for enhancing groundwater monitoring and communication to be:

Highest priority

1. Enhanced data gathering and communication by the NSW Office of Water, including telemetry of selected bores – levels on monitoring bores and levels and quality on irrigation bores

Secondary priority (these vary across zones)

2. Supplement the NOW data with additional monitoring.

Lower priority

3. Independent analysis of existing data sets.

Priority 1: Enhanced data gathering and communication by the NSW Office of Water

Improving the collection and communication of data from the existing network of government monitoring bores was considered to be the highest priority.

This would include:

- Hydrographs / data on website;
- Status reports; and
- Meetings once a year to review trends.

It was widely acknowledged that there have been less resources allocated to groundwater monitoring in recent years and less hydrogeologists on the ground. Resourcing was seen to be a key issue that needed to be addressed. Several groundwater users noted that they are paying for this monitoring through their licence fees and therefore the NOW should be allocated the resources required.

While it is the responsibility of NOW to monitor and report on the groundwater condition, the restriction in resources for this task have meant that it is not being done to a satisfactory level. As it is such a high priority, if additional resources are available for groundwater monitoring then the potential to co-invest to improve the monitoring and communication of groundwater data from the NOW should be investigated.

Groundwater quality

The existing NOW monitoring program looks at levels, there is not a routine groundwater quality monitoring program in the Namoi. There is scope to develop and resource this area.

Telemetry of selected bores

Telemetry is currently being installed on selected bores, including 30 monitoring bores across the Namoi and pump bores in a few areas to enhance the government monitoring program (funded by NOW and the National Water Commission). These will be connected to a website to enable real time presentation of data (as hydrographs) of water levels in those bores. Once a quality check has been conducted then the data will be incorporated into data sets.

Groundwater users saw this as a very positive initiative. They suggested there may be scope to further enhance the telemetry program by:

- **Adding EC meters** to the monitoring equipment on telemeted farm pump bores (it would not be accurate on monitoring bores where the water is stagnant). This would involve some additional cost in equipment installation but the additional on-going cost would be relatively low.
- **Extending the telemetry** to include more bores (over time).
- **Commitment to long term continuation and maintenance** of the telemetry program. Groundwater users were concerned that NOW have committed to maintaining the telemetry until 2012 and it is unclear as to how they will be maintained after that time.

Priority 2: Supplement the NSW Office of Water data with additional monitoring

Groundwater users considered it important to have more information about the condition of the groundwater resource - both quantity (levels) and quality.

There was some variation as to the best way to collect this information and a zone by zone approach will be warranted. The key approaches to be investigated further with each zone are:

A. Groundwater users submit samples/data to a coordinated monitoring program

B. Groundwater users gather data and keep their own log

C. Independent data gathering from monitoring and/or pump bores.

A. Groundwater users submit samples/data to a coordinated monitoring program

There are varied views on whether a coordinated program is a good idea. It is worthwhile investigating the costs and potential resourcing options for such a program. If this is not prohibitive, develop a broad approach and then work with each zone to determine whether a critical mass of groundwater users in that area are interested in participating and to refine the methodology. Some areas in the Upper Namoi were interested in participating and many individuals across other areas of the Namoi were interested. A list of names of those people who were potentially interested in participating will be provided separately from this report.

B. Groundwater users gather data and keep their own log

This was the preferred option of the Lower Namoi groundwater users and some Upper Namoi users.

It involves groundwater users undertaking their own, on farm monitoring program and keeping a record of quality and/or levels. There was seen to be value in having a consistent methodology for this so that groundwater users could come together to compare their results.

C. Independent data gathering from monitoring and/or pump bores.

This was not widely discussed at the workshops but may provide to be a cost-effective option for gathering robust data.

Relative merit of different options

Groundwater users are most interested in having sufficient, robust information. There is need for information that is wider than the farm scale – ie the condition of the resource as a whole / in a locality. This is in theory provided by the NOW program but it could be improved in timeliness of reporting and may be supplemented with a groundwater quality monitoring program.

Option A would likely be the lowest cost option but will not provide an additional data set that can be reviewed across the region.

Options B and C would be higher cost but do gather additional data. Option C (independent analysis) was not widely discussed in the workshops or considered a high priority by groundwater users. However, in making decisions about allocating resources to supplement current monitoring programs it would be worth considering the relative cost and data quality from each of the above three options.

Data from Option C can be expected to be more rigorous and comparable but does not achieve the participation of groundwater users possible through Option B. Community monitoring programs are often undertaken for the sake of engaging community members in monitoring and understanding the resource. In this case, engagement does not appear to be the primary need as most people are already interested in seeing information - and those who aren't may be unlikely to participate in a monitoring program

There is value in encouraging groundwater users to keep track of the condition of their resource. However, if they have no options to vary their management then this can be difficult to justify.

6. Recommendations

There is scope and demand for improving the collection and communication of information about groundwater condition in the Namoi. The new telemetry program will go some way to help this but is not the complete solution. Improvements to the groundwater monitoring program will be heavily influenced by available resources and priorities. It is not possible to prioritise these recommendations without an indication of budget.

Recommendation 1)

Work with the NSW Office of Water to develop an approach to enhance their program of groundwater monitoring and communication in the Namoi

Identify opportunities to enhance the existing groundwater monitoring program to enable communication of groundwater condition results at least annually and periodic monitoring of groundwater quality.

Identify and act on the potential to further enhance the telemetry program by:

- Adding EC meters to the monitoring equipment on telemeted farm pump bores.
- Extending the telemetry to include more bores (over time).
- Gaining commitment to long term continuation and maintenance of the telemetry program.

Recommendation 2)

Develop and promote protocols for groundwater users to gather and track their own groundwater data and encourage discussion of findings

With relatively little investment, existing Cotton CRC and Namoi CMA project staff could develop a set of standard protocols for groundwater users to follow in their own on-farm monitoring and tracking of groundwater quality and levels. A standard approach will enable groundwater users to come together to compare their results.

It would be worthwhile to pilot test the protocols with the Lower Namoi groundwater users who suggested this approach. Promotion and encouragement will be needed for the protocols to be successful.

Opportunities for enabling this include:

- Develop a standard methodology, including sampling techniques, timing of sampling, handling of samples, quality parameters to be analysed for and recommended laboratories for analysis. Existing Cotton CRC fact sheets and the information developed for the may serve as a useful starting point for the protocols.
- Encourage groundwater users to monitor and keep a log of groundwater condition.
- Provide training and advice in interpretation of results.
- Develop and provide a log book for monitoring.

- Facilitate forums (eg annually) for groundwater users to compare results. This will likely need to be arranged and facilitated by a lead organisation such as Namoi Water, Cotton CRC and/or Namoi CMA.

This recommendation could be incorporated into an existing project, such as that being undertaken by Kate Lightfoot.

Recommendation 3) Improve communication and promotion of data about groundwater monitoring

Use a combination of methods to distribute information at least annually before water use decisions are made for the summer season.

This would include:

- Status reports, including interpretation of the data distributed via email (or post where required) and available on the internet.
- A series of winter meetings to discuss the findings;
- Data and hydrographs on a website with real time information; and
- Promotion of information sources and release of new information/reports.

Some information is already readily available, but many groundwater users are not aware of it, promotion of these information sources is warranted, particularly when new information is posted on the internet.

Recommendation 4)

Supplement the NSW Office of Water data by supporting additional independent monitoring

Periodic investment in independent groundwater quality analysis is recommended (unless this has been added to the NOW program through negotiations in relation to recommendation 1). If the NOW data communication is unable to be improved then additional independent monitoring of groundwater levels may also be required.

This may involve contracting or employing someone to measure levels and collect samples for quality analysis. This could be from both monitoring bores (with agreement of NOW) and/or from farm bores. Generally it is more time consuming / costly to monitor private bores. Interpretation and analysis will be required in order to gain value from this additional data. This could be done on a periodic ‘one-off’ basis as has been the case with this current project or on an on-going basis.

Recommendation 5) Further investigate the benefits, costs and implementation options of a coordinated monitoring program

Many growers have indicated that they would be willing to participate in a groundwater monitoring program. However, the reservations they have about such a program mean that it is not the highest priority. A first step will be to identify the costs associated with a coordinated groundwater user monitoring program. If these are considered acceptable in relation to other options, then a groundwater user monitoring program can be developed that includes:

- Sampling at the start and potentially also the end of the summer irrigation season (ie August/September and February/March);
- Standard, robust, easy to follow methodology for sampling procedures;
- Quality checking;
- Centralised analysis and interpretation;
- Rapid feedback on individual analysis and interpretation of results across region/zone (within 2 months);
- Comparison of findings with NOW data sets;
- Confidentiality of data;
- Recognition of the limitations and ownership of the data; and
- Funding of coordination and monitoring equipment.

It should be made open to all groundwater users in the Namoi but focus particularly on interested sub-ground (eg localities or zones where people are most interested).

There may be potential to incorporate a grower sampling program together with independent analysis suggested in recommendation 4.

GHD

133 Castlereagh St, Sydney 2000

T: 2 9239 71006792 5330   F: 2 9239 7199   E: ingrid.roth@ghd.com

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
	Ingrid Roth	Jan Paul van Moort				

Appendix B1 Survey questions

1. Telephone survey

<u>Groundwater Monitoring and Evaluation and Grower Survey for the Namoi Catchment</u>

GHD Hassall in conjunction with the University of New South Wales Water Research Lab are conducting surveys with growers in order to gain an understanding of growers' view about groundwater monitoring, knowledge and willingness to participate in order to design a strategy for increased grower participation in groundwater monitoring. This work is being done for the Cotton CRC and Namoi CMA.

All information will be treated strictly anonymously.

Background Info:

Name: Phone:

Groundwater licence type: Irrigator / Stock and Domestic

Uses of groundwater: Irrigated cotton / Irrigated grains / irrigated lucerne / irrigated pastures / Stock / Domestic

Property Name & Locality:

Groundwater zone:

{if needed look up the Tech report for zones}

In the month of July, this project is offering free partial analysis for the first 200 groundwater samples sent in for testing.

Have you sent in a sample for the "Groundwater in July" testing? Y / N

Are you interested in this? Y/ N *You can collect a sample bottle, a form and more details from Namoi CMA, Cotton CRC or Namoi Water.*

Part 1) Attitudes and Perceptions about Groundwater Monitoring

1. Broadly, what are your own thoughts about groundwater monitoring in the Namoi?
    a. What do you think are the benefits of monitoring groundwater condition?
    b. Is there currently enough monitoring?
    c. Have you sought information about groundwater condition and monitoring?
    d. If so, was the information readily enough available?

       If no, what are the gaps in the information?
    e. What do you think could be done to make information about groundwater condition more readily available (if needed)?
2. How important is the groundwater resource to your enterprise?

Part 2) Current monitoring activity

3. Do you think it is important for groundwater users to monitor groundwater condition?
    a. Why?
    b. For what purpose?
4. Do you currently monitor your bore? Yes / No

    Why / why not?

    Is it actually possible to monitor water levels on their bore? Yes / No / Don't know

    If yes they do monitor:

    a. How often do you monitor?

        Daily / weekly / monthly / quarterly / annually / occasionally / once off /…………

    b. What do you monitor for? Water levels / Quality – ph, EC, other………………..
    c. How do you measure this? Quality: EC meter / lab analysis / other…………

        Levels: Automated guage / manual dip / other…...
5. Do you test bores before using them for drinking? *(question may have been answered in above)*
6. Do you have a meter for measuring water quality? Y/N *(question may have been answered in above)*

    If yes:

    a. How often do you calibrate the meter?

Part 3) Knowledge about Groundwater Levels and Quality

7. Do you think groundwater levels are changing over time (long term, seasonal)?
    a. Have you detected changes in groundwater levels?
8. What factors do you think cause changes in the groundwater levels?
9. Do you think that groundwater quality is changing?
    a. Have you detected this? eg through monitoring or crop reactions?
10. What factors do you think contribute to changes in quality?
11. Have you made any changes to your water use patterns as a result of changes in water levels or quality? Yes / No

    If yes, what changes?

    {eg. Levels: lowered pump, changed operating times, don't use 2 nearby pumps simulataneously

    Quality: Mix with other water}

    If no, why not?

Part 4) Participation in a Coordinated Monitoring Program

12. Do you see value in landholders contributing their monitoring data to a coordinated groundwater monitoring program? Y/N
    a. Why / why not?
    b. Any concerns?
13. Would you be willing to share data through a co-ordinated program? Y/N/Maybe

    If yes:

    Would you like us to include your name on a list of people interested in monitoring that we will provide to the Namoi CMA and Cotton CRC?
14. What things would stop you from doing this? *(barriers to participation)*
15. What would encourage you to regularly monitor bores and share that data through a coordinated program?

    (If funding is not available, what else may encourage participation?)
16. Who do you think should co-ordinate this data?
17. How should data from a coordinated monitoring program be displayed/communicated?

    Maps / web interface / reports / meetings or workshops / other…………………
18. How often should this information be made available?
19. Do you have any other comments or suggestions about groundwater monitoring in the Namoi?

2. Written survey

This survey was a part of the form submitted with groundwater samples sent in for analysis in the "Groundwater in July" program. The introductory letter and form follows.

June 2009

Dear Namoi Groundwater User,

NAMOI GROUNDWATER SAMPLING MONTH - JULY 2009

This July we are encouraging groundwater users (irrigators and stock & domestic) to collect a water sample from their bore for a FREE partial analysis*.

Sampling bottles can be collected from Namoi Water, NSW Farmers, the Cotton CRC and the Namoi CMA. Monitoring and understanding the status of groundwater levels and groundwater salinity is central to managing this valuable resource and is being helped by this project commissioned by the Cotton CRC and Namoi CMA.

Groundwater level and salinity is being monitored this January, March and July by the University of New South Wales' Water Research Laboratory (led by Dr Wendy Timms). By combining this information with monitoring by the Namoi CMA, the Department of Water and Energy (DWE) and other groundwater projects, Wendy and her team are drawing a picture of how groundwater condition varies over time and across the Namoi.

The project also seeks to understand how groundwater users may get involved in on-going groundwater monitoring and management. Ingrid Roth and her team from GHD Hassall will contact many groundwater users to gather their ideas on this. We encourage you to discuss your thoughts with them and assure you that your views will be treated confidentially.

Samples provided by growers will add value to the data review. The project will lead to establishing a framework for benchmarking groundwater quantity and quality.

Yours sincerely,

Paula Jones	Bronwyn Witts	John Clements
Cotton CRC	Namoi CMA	Namoi Water

If you have any questions, please contact ourselves or the project team:

UNSW Water Research Lab
Wendy Timms & Duncan Rayner
02 9949 4488
d.rayner@unsw.edu.au

GHD Hassall
Ingrid Roth
02 6792 5330
(not available 19 May – 1 July)

* The first 200 samples received will be analysed for free, any further samples may need to be charged at a cost of $100/sample.

Namoi Groundwater Sampling In July

A program for Namoi Valley Groundwater users to get involved in testing their bore water quality

Why test groundwater quality in the Namoi Catchment?

Groundwater quality has been found to be a significant issue in some parts of the Namoi Catchment. Operating a groundwater bore without monitoring groundwater level and groundwater quality is "like running a car without a fuel gauge or a dip stick".

What water quality parameters are being tested?

Salinity (electrical conductivity, EC), pH, chloride, sodium, magnesium, calcium, potassium, sulphate and bicarbonate alkalinity. These results will be used to calculate indicators of importance to irrigation usage (total dissolved salts, sodium adsorption ratio and hardness).

Who will take the samples?

Growers and landholders that use groundwater on their property for stock or irrigation purposes. Any growers and landholders in the Namoi catchment can participate in the sampling.

How do I get involved?

Pick up a groundwater sample bottle pack from Namoi Water, NSW Farmers, Cotton CRC or Namoi CMA offices (Tamworth, Gunnedah, Narrabri, Walgett) from late June.

This pack will have further instructions about sampling and information that needs to be recorded. If you have access to a water quality meter, measure EC and temperature should be measured immediately when the groundwater flows from the bore. Record this information on the form.

Completed samples can be mailed to UNSW WRL using the mailing pack supplied.

Why collect samples in July?

Groundwater systems in the Namoi are generally most stable in July, thus giving the most accurate readings. This will also coincide with a round of sampling being undertaken by the research team.

Can I use any sample bottle?

No. For quality assurance purposes, registered laboratories do not accept recycled bottles.

Why pump before sampling?

Pumping for at least 15 minutes prior to sampling is essential to purge stagnant water from the bore casing.

Where can I get a water quality meter?

The Namoi CMA has a few EC meters for loan (contact George Truman on 6742-9516).
A basic meter can be purchased for about $150. Further information on where and what to purchase is available on the "DIY Groundwater Monitoring" factsheet on the Cotton CRC website.

How much will it cost?

FREE analysis is being offered for the first 200 samples received provided that these are:

- collected between 1st and 30th July, 2009
- accompanied by a completed sample information form
- one sample per property (preferably from the most frequently used bore)

The Cotton CRC and Namoi CMA are funding the once-off cost of about $150 per sample. If you would like more than one sample to be analysed from your property or if your sample is not amongst the first 200 received then these can be analysed at a cost of $100.

What happens to the testing results?

Sample results will be posted to participants in September, with a 2 page report providing a comment on the suitability of groundwater for irrigation purposes.

Results will be treated anonymously. The data will be grouped and mapped for each aquifer and reported in aggregated form. These maps will be provided to participants and will also available via the Cotton CRC and Namoi CMA websites.

Where do I find out about more comprehensive water quality testing?

This project will be testing for major ions. It will not be testing for microbiological, nutrients, or other trace constituents. Comprehensive tests are recommended for bores used for other purposes such as drinking water, if there is a risk of nearby contaminants, or if there is potential for mining impacts. Suggested contacts: Tamworth Environmental Laboratory ph. 6767 5119, DPI Wollongbar Farm Water Testing ph. 66261103 or Australian Lab Services ph. 8784 8555

Further information:

http://www.wrl.unsw.edu.au/site/projects

Duncan Rayner

d.rayner@unsw.edu.au, 02 9949 4488

This project is funded by the Cotton CRC and Namoi CMA

Namoi Groundwater in July - Sampling Form

Collection Notes:

- Collect the water sample from a freely flowing bore (ie, at pump outlet or spill point)
- Pump must have been running for at least 15 minutes, prior to sampling
- Rinse the collection container with at least 3 volume of sample water before collecting a sample for measurement.
- Follow manufacturer calibration procedure for the conductivity or pH probe before each measurement.
- Label the sample bottle with the Bore Work No. or your name, sample date and time.

Your Name	**Date**
Property Name	**Sampling Date:** **Time:**
Address	**Email**
Groundwater Zone	**Slotted Interval / Intake – Top** (metres)
Date Borehole Installed	**Slotted Interval / Intake - Bottom** (metres)
Location (from GPS or map – if known) Easting: Northing:	**How long was the pump running before sampling?** (minutes)
Bore Work No. (or License Number):	**Bore reference point (if known)** **Top of Casing:** (m) **OR Ground Level:** (m)
Borehole Total Depth (m)	**Depth to groundwater** (m from reference point)

Do you have a meter for measuring water quality: **pH?** Yes / No **EC?** Yes / No **If yes, how often do you calibrate the meter?**	**How frequently do you monitor groundwater quality?** ☐ Weekly ☐ Monthly ☐ 3 monthly ☐ Occasionally ☐ Other……………

If possible, please take measurements of the water at the time of sampling and record these below
(NB most EC meters can also measure temperature)

Temperature of Water: (^{0}C)	pH of Water:
Electrical Conductivity (EC) of Water: (dS/m)	

In your view, how important is it for the groundwater condition to be monitored regularly? ☐ Very important ☐ Somewhat important ☐ Not important ☐ Don't know Comment:	**Do you feel you can access information about groundwater condition in the Namoi?** ☐ Yes - Readily ☐ Yes - but not easily ☐ No ☐ Have not tried to

Do you see value in landholders contributing their monitoring data to a coordinated groundwater monitoring program? Yes / No **If yes, who do you think should coordinate this?** ☐ DWE ☐ Namoi CMA ☐ Cotton CRC ☐ Namoi Water ☐ NSW Farmers ☐ Cotton Australia ☐ Other……………	**How do you think information from groundwater monitoring should be communicated to users?** ☐ Data on website ☐ Research reports that review changes in groundwater ☐ Newsletters ☐ Workshops ☐ Groundwater user meetings ☐ Other……………………….
Would you be interested in participating in on-going groundwater monitoring activity? Yes / No **If yes, how often would you be willing to monitor your groundwater?** ☐ Monthly ☐ Quarterly ☐ Annually ☐ As often as required	**How frequently should this information be made available?** ☐ Annually ☐ When any critical changes are detected ☐ Other …………………….
Would you be willing to share your data through a coordinated program? Yes / No / Maybe **If maybe, what would enable you to do it?** **If no, why?**	**Please make any other comments about your thoughts about Namoi groundwater condition and monitoring**
What would assist you to participate in groundwater monitoring and share your data? (Please list at least 2 ideas)	

Groundwater sample testing permission

I ____ (name) provide this groundwater sample collected from a bore located on my property for a major ion analysis. I understand that the first sample per property will be analysed free of charge, provided this is amongst the first 200 samples received.*

If my sample is not amongst the first 200 received I would like the WRL to *(please tick)*:

☐ Complete the analysis and invoice me for $100
☐ Discard my sample without analysis.

I understand that my data will be treated anonymously and will be used in an aggregated form for reporting and analysis by the Cotton CRC, Namoi CMA and researchers at the University of New South Wales Water Research Laboratory.

Signed ________________________________ Date ____________________

* Additional samples can be analysed at cost, please complete a separate form for each sample and include a cheque made out to "University of New South Wales" for $100 per additional sample and send with the sample to the UNSW Water Research Laboratory, 110 King St., Manly Vale, NSW, 2093.

Appendix B2 Detailed responses from telephone surveys

Following are detailed responses to some of the key topics discussed in the telephone interviews.

1. Views about the importance and benefits of groundwater monitoring

Importance / need

- Very Important (X11)
- Important (X13)
- Good idea (X3)
- Any water monitoring is good
- yeah I guess its important
- Groundwater is like a dam but is underground - you wouldn't imagine not monitoring levels on a dam so why not on aquifer?
- Particularly in current climate with possibility of mining licences to be granted
- Really important back in the drought when river was low.
- It’s a good idea, I think its very important
- Monitoring GW condition is very important. Worried that with BHP there are no regulations. It is open slather. If mines get the go ahead it will be open slather.
- Needs to be done so we can see if there is any contamination
- it should be done
- In favour of monitoring
- Should be done
- Everyone’s gotta do it
- In dry years its essential
- Good idea to keep an eye on the aquifer
- Monitoring is important to know what’s going on and to get on top of any issues
- Yes I thinks its really important if its done accurately and honestly
- Well we have to test the water every 3 months because we're a dairy
- Paramount that monitoring be done. It is pretty depleted along river. It needs years of nil usage in order to let recharge happen. About 20 years ago there was 300 days of surplus flow which allowed for it to recharge. Probably will recharge from Great Artesian Basin.
- I think its really important that the testing is accurate, people fiddle with meters particularly broadscale irrigation, its really open to constant abuse.
- There are issues with groundwater around Maules Creek
- Need to know data to know what is happening - some individual farmers would know

What to monitor?

- Particularly usage/levels - can't have an open slather! I guess that's why we have a meter.
- To know whether the water level is increasing or decreasing
- To understand where GW levels are changing and in which areas
- Important to know how much is in there. The recharge capacity and to use it sustainably
- For contamination purposes
- Also to monitor GW quality. This is also ensures that there are no contamination issues. The GW table in this area is also shallow and there is major erosion in creeks
- To monitor the long term GW level trend
- Should monitor quality
- Understanding the quality, determining whether salinity had increased and whether there was any change in aquifer condition
- Everyone is most worried about the levels rather than quality
- Quantity issue is important. Quality - notices a problem when dry but not a salts issue
- Main benefit for me is changing aquifer levels. Not sure about quality - I think they'd only be subtle changes.
- To know when levels are dropping and for things like sodium, to know what’s happening

Benefits – allocations, sustainability

- Need information so can understand what is happening with the aquifer. In the late 1980's, early 1990's there was transparent management from the department - based on that monitoring growers identified that use was unsustainable.
- Need it so can know the trends so as to be able to manage the resource proactively rather than reactively.
- To know where the levels are at any given time and I think it would be really useful to know the levels of water going in and out for both economic and environmental purposes
- To manage the groundwater resource we need an intimate knowledge of what is happening. We're not yet half way through the 10 year groundwater management plan so we need to monitor levels to determine if the plan is achieving sustainable use.
- Need to understand short term vs long term variability
- Yes it's essential as it provides concrete data of what is and has happened and then decisions are able to be made.
- Gives you a pretty close indication of sustainability.
- To know what the levels are doing and set allocations accordingly.
- I think there are benefits so we know what the water is up to and so there are no more cut backs if its not needed
- More sure it is a sustainable resource and to get a better understanding of extraction and recharge
  It tells us if groundwater levels are being replenished, whether farming practices are causing it to increase or decrease, whether recharge is occurring.
- Important in getting a picture of water resource.
- Long term sustainability
- To know what we are dealing with
- Helps understand and maintain the condition if the aquifer
- To understand the environment and know what you are pumping
- The GW adjustment program was flawed.
- Groundwater has been shockingly managed. The cotton industry has always been too strong for the department.
- To collect data and understand the condition of the resource to inform decision making (provide the Department with accurate information on which to base changes in allocations).
- To find if the level of irrigation is sustainable
- To understand the quantity of water available for sustainable irrigation
- To sustain the quality and quantity of the GW condition
- To know that you are pumping within the sustainable yield of the aquifer
- To ensure that water is not overused or contaminated

Benefits – understanding mining impacts

- Able to develop a baseline to benchmark against in case mining ruins landscape
- To see changes in quality particularly with mining coming
- Yes, mining companies are doing monitoring. There may not be credible with “BHPs drilling and they might be falsifing their log book.”
- The other benefit is that of coal mining as it has the potential for closing off of aquifers and redirecting them.
- To make sure the coal mining companies don't pollute the aquifer.
- It's a great idea for monitoring the aquifers, especially with the gas and coal exploration that's going on. It's very important for us to get a base level and quality testing, so that we can tell if the mining activities have any impact on the groundwater system. It will be very important evidence.

Quality - suitability for irrigation

- To understand the quality to ensure that soils are not degraded and crops are not being adversely affected by saline water
- Need to keep an eye on the quality for irrigation and domestic use
- Knowing what’s on your crop, aware of change in quality and ongoing observation

Other

- No benefit. Would be benefit if water levels declined.
- I don't really know
- Happy to be involved
- Concern about what will be done with data and mining.
- Most interested if water is there - don't get much into it.

2. Perceptions about whether there is currently enough monitoring

Yes, I think so

- Yes (x9)
- Possibly. People in department are currently doing it, both monitoring and testing bores.
- In some areas
- I'd say so, I think there is enough there just needs to be some fine tuning
- Monitoring bores are around
- The department have test bores and do the monitoring
- Must be being done as they had something to base reduction in allocations on. Department has excellent information but issue is how they use it. Resources are gone in the department.
- Yes, there's a test bore out the front of our property. The Department of Natural Resources comes out and tests the groundwater. Not sure how regularly though, or what they're actually testing.
- There seems to have been a huge amount of monitoring over the last few years from the government, and we've had a lot of allocation cut backs
- I thought GW monitoring was something that was done each year. Measures what's coming out rather than what's coming in.

Probably enough but we don't hear…

- It may be happening but the collation and reporting back to groundwater users is missing so we don't know if there is enough monitoring.
- Probably but don't get the information
- Electronic monitoring of bores is being put in place, to come on line later in the year - but concerned that they may not have used the best bores in each zone to give a good indication of trends.
- There is a lot of monitoring going on but I'm not sure whether the readings and results are getting back to the Farmers
- Not enough information is given back to farmers
- Get hardly any info
- Well there are a few test bores around us that the water resources monitor, we never see the results but I think if we rang and asked we could get them

Not enough

- No (x14)
- Probably not (x3)
- Now it is going nowhere - government is hopeless.
- More needs to be done
- I don't think so particularly the levels, people just don't understand that levels are decreasing
- Probably not enough monitoring but there are probably enough bores. It is only done manually and there are only 1-2 staff.
- I don't think so, the DWLC used to do some but I don't know what's happened to that now
- Like to see more monitoring
- Council has done some in the last 12 months but hasn't given anyone any feedback.
- They only monitor on usage so that the dept can send them bills. The department used to do monitoring in the Namoi Valley. They overpumped ten years ago and they were cutting back usage and unutilised bores. This resulted in overuse / forced use
- There needs to be more testing done
- Its got to be done provided the figures are not fudged by the department. I have become very disillusioned with the departments monitoring.
- Very limited
- No because it is an expensive exercise

Don't know

- Not sure (x8)
- Not sure what the department is doing but if it is doing its job then there should be currently enough monitoring. They are certainly watching the bores. Its hard to comment. Monitoring over the history of bores has been excellent.
- We haven't noticed the CMA or Department doing any monitoring. We've attended a few CMA information days at Tambar Springs, which were really interesting. After the 2000 flood, they mapped water flows. It was great. Not sure what other landholders are doing.

- Difficult to say we are definitely engaging in monitoring.
- No-one seems to be checking the government bores.
- Department does salinity, monitoring bores - don't know how often.

3. Views about participation in a coordinated groundwater monitoring program

Rigor / accuracy of data

- A good network of independently monitored bores is better.
- If it was accurate then I would see no problem in that.
- There's lots of benefit to knowing what's happening but it has to be truthful, I think it really needs to be independent.
- the contributions need to be genuine and not distorted to give an accurate picture
- If it is all consistent
- There is value in a coordinated monitoring program but data can be deceiving and pumping activities by neighbours can add noise to the data set which may be misleading.
- Depends on quality of data - QA process and checking
- Too much variability in how samples are collected by different people. Need a more rigorous process. It won't work if you rely on individuals picking up bottles for sampling - would need to be mailed out at a regular time, etc. Even at recent meeting only about 10% of people collected sample bottles. Especially for quality, need right processes, containers, dispatch - where to? EC / PH meters - would this be monitoring enough?
- Risky - don't know how the data has been taken - credibility and accuracy is questionable.
- Unreliable
- Main concern would be if they were not accurate. Main issues would be if people
- If contributions are distorted it will give a distorted picture which is pointless
- Won't work if people were fudging results for their own means or if people do not participate.
- I don't think people are honest enough to do it (speaking from zone 11 experience)
- Would have to be done properly, lay down some guidelines.
- Quality of data collected, untamperable meters, scientific involvement would be required.
- Depends on the coordinated process
- Data quality is a concern, particularly if it is used make decisions in the future. Farmers are not trained to test GW accurately.
- We need a reliable, rigorous pool of data and grower data is not enough
- Independent people taking samples would provide an unbiased view of what's going on
- Is it valid? Would stand by own data but not sure of others.

Need?

- Should have enough data from monitoring bores
- Information should be available now from the water resources
- it should be left to the department to do the monitoring
- DWE has 500 test holes across the Namoi. All are locked you cannot access them. they are not being read on a regular basis and tests are not as meaningful.
- I value the independence of the department
- It would be easiest to monitor the data that the Department collects out the front of my property.
- but they should do it when water is tight and cut back allocations earlier, not just at the last minute, or they should put a time limit on the time people irrigate for.
- Department undertake the testing
- We have already been tested before and there are government bores very close to our place.

Benefit of a coordinated groundwater user monitoring program

- To have more data across farm areas, own bore monitoring is probably not enough even within season - need to see from a broader area
- Get a lot better picture with more testing going on.

- The more information available, the better decisions that can be made
- Provides more data
- Wouldn't object to a coordinated program as I don't waste water.
- Negligible value as have own data
- The operators of bores have data. The government may not fund it. We should be made to monitor our bores. The system has to be monitored.
- There are vast differences in readings from zones
- A program would be valuable if there was a positive outcome for growers.

Benefit of monitoring by groundwater users

- It would be good to see if there has been a benefit after the allocation cut backs and if it meant more informed decisions in the future
- At least if a few in the area were doing it it would be good to know, particularly quality
- Real merit around Boggabri we tried to do this and supply dept with information every couple of months. We found that our GW tables not falling in line with other areas.
- It's really important
- Probably in the long term it would be good
- We were one of first to go to a water sharing plan in this region.
- So we know what's happening across the area
- To ensure the resource is sustainable
- It's essential
- To see how the system is going
- It would be useful
- To collect data and understand the condition of the resource to inform decision making (provide the Department with accurate information on which to base changes in allocations).
- More information available on GW zones to plan for the future
- To have a picture of the area/GW Zone not just own property.
- Enormous value in the data
- Need to know the state of the GW, especially for the graziers using it for stock
- To keep tabs on whether water use is sustainable

Cost

- Users shouldn't have to pay for the monitoring service and also do that service. Licence fees are high and should be used by the department to do independent, scientifically rigorous monitoring to maintain the asset.
- If the dept got stuck then yes it would be useful. The way things are we have to pay more and the dept may drop out.
- We are overcharged as it is. The Govt should be doing it and not charging. We originally had unrestricted licence and an allocation on charge of $100 each year. Now this is up to $2-3000 per year and this has all been over 20 years. The govt should be doing it on their own back. The $100 originally covered the cost of putting meters on bores and the cost of reading the meter. We are not getting anything extra today. Some people don't even have allocation and are still paying this each year.
- Costs associated for landholders.
- We wouldn't want to pay for it.

Data use and ownership

- Not sure everyone would want to know - Some would want to be anonymous.
- Concern about data being publicised before know the ramifications. Eg hotspots have publicity
- the data could be used against us instead of trying to help us
- Don't trust what would be done with the data – might be used against us - has been done in past.
- We wouldn't be willing to necessarily hand over data as we have spent a lot of money and resources in collecting that information.
- I wouldn't give the information to the DPI, I wouldn't want them to get their hands on any of our results
- Sceptical of the Department's use of data.
- Coordinated data may be used against GW users

Practicalities and regularity

- I could monitor depth from one of my bores without too much trouble, but not the other two - it would be too difficult unless they were getting pulled up for a service.

- The farmers are the ones at the wells, therefore they'll notice the biggest differences.
- Depends on the type of monitoring and if we had test flows. It would provide people with a benchmark.
- Very much location dependent.
- I think the organisation of it would be difficult and hard to get farmers to do it and get all the data together, I think a government organisation needs to do it.
- Happy to send in regular samples for quality monitoring, need a reasonable system - collect a couple of times over winter and monthly during season.

Time

- Time, people don't get round to it, too busy with other things
- Have too many other things on
- Having enough time to do this
- If there is time to monitor, these things often end up being slowed down by red tape

No concerns

- No, up until three years ago we had quite regular meetings. I think actual landholders using water are very conscious of quality. The big arguments used to be sleeper licences.
- No we are all in the same boat.
- No
- No

Other comments

- Haven't had feedback from involvement in previous monitoring projects
- We are in a coal exploration area, so we have had our bores tested properly and have had it tested twice in the last 6 months.
- Only use it as an emergency back up supply.
- Would only be of value if it was in my interest
- Quality also would be useful.
- Don't want the water issue stirred up anymore, only likely to lead to more cutbacks, not water allocated back.
- Better investment to do sentinel bores with good modern equipment and telemetry, perhaps supplement with grower monitoring.

4. What could be done to make info more readily available?

Communication and promotion

- Communicate monitoring data to GW users. The department is undertaking monitoring but does not contribute results
- Regularly inform GW users of information from readings and results
- Promote publicly available GW data (tested by the Department)

Ways of getting information

- Status reports and winter meetings as had been done in the past (this was good) and access to a website with data. The direct communication is important for interpretation and explanation.
- As in past - status report + winter meeting for interpretation. Also data on web.
- Published and circulated within catchments
- Flyers, emails, website (x2) - we don't want to have to hunt for the information!
- Newsletter by post (best) or email

- There's no communication about how or where to get the information that's collected. A website would be good, with all of the test results. That would be really useful for me.
- Website (x6)
- Website and report
- Telemetry devices, online data
- Web access to live data / hydrographs (x2) This would be most cost effective and save need for roadshows. Make a sample of bores volumetric so can dial in to see data - need all 3 levels of aquifers. It is high cost but irrigators are paying a fortune in licence fees.

- Not sure but it should be put on a website
- Website with promotion
- Database online

- Report (x5)
- A report direct to growers perhaps distributed at landcare meetings
- Maps - needs some interpretation. May be potential privacy issues with data from community program?
- Website is good but I think people might take more notice if it was sent with maps and a report
- Graphs

- Mail is the best for us (x5)
- I would prefer to receive a printed addressed letter or fax. I am not an internet person and you sometimes miss things if it is in a newspaper. You tend to notice things more if they are addressed to you.
- Hard copy or printed form so I can read it over breakfast or lunch.
- In a letter format

- Email (x8)
- Fax (x2)
- Emails to get results quickly, good if have notes about relevance. Presentation in winter (June-July) Sep't a bit late.
- Electronically, individually, status report
- Anything that comes in on email, you tend to read. Regular email updates or e-newsletters would be great.
- Mail out, email - of data and interpretation
- Mail or email
- Send the information via email - we don't have enough time to attend field days or workshops.

- Seminars to explain how to use the data
- Should be through John Clements and he should have meetings once a year
- Workshop/seminar
- The local landcare groups are very active in the area, they provide a good source of information and a large no. of growers are involved with landcare.
- Regular meetings in a local areas where a hydrologist should show graps of the last twelve months compared with the previous 12 months. There should also be data from 30-40 test holes and records of pumping, and records based on meter readings.
- Namoi Water have had a meeting but this is an irrigator's thing
- Workshop/seminar

- Email and seminar (x5)
- Leaflet and email
- Local presentation and mail (x2)
- Email and websites are great for regular updates, and workshops tend to reinforce the information.

- Distribute information from test bores to surrounding licence holders

- Not fussy as long as its recorded and is there when required.

Specific comments about distribution of data from community monitoring

- Dependent on how it was going to be used.
- Data should be kept in confidence for the use of growers only
- Web interface with an annual meeting (like the current GW zoning meetings)
- Suitable to the quality of the data eg not glossy publications for limited, unreliable data
- Its not necessary, the information is available already. DWE have been testing and they have the information already available

Speed and timing of information

- Had hoped that the work at Maules Crk with automated loggers would be an indication of how much quicker information would be available but not so sure it will make a difference.
- It would be interesting to get feedback from council on a seasonal basis (Dec-Mar).

- Needs the most up to date information in relation to quality and levels. The meetings are good as you can ask questions and an email reminder is useful.

Type of information

- Want accurate data - however they can get it accurately
- We appear to not have the same problems as further up the valley with flow and recharge.
- Stop being so secretive, just tell us the truth about water levels whether they are right or wrong we just need to know what's out there.
- they could make results available but that would be more costly to us
- I suppose if regular information was sent it would be good because there have been cut backs of up to 75% and it would be good to see the research behind it

Awareness of information sources

- Growers should be responsible for themselves and their own monitoring. I guess we need to know who to go to to get information, just don't know what's out there.
- more regular monitoring by growers and the department
- I guess education on how to access the information
- Advertise the benefits of using GW info

- I guess when they test levels on observation bores they could test for quality as well
- We have own info

Appendix B3 Workshop Agenda and Notes

GROWER GROUNDWATER WORKSHOPS

31st August 4pm Gunnedah (Zone 3 only)
1st September 2009 8am Wee Waa Bowling Club; 3pm Gunnedah Services Club

8 am	3 pm	Welcome and overview of workshop	Ingrid Roth
8:05 am	3:05	Background to project	Paula Jones / George Truman
8:10	3:10	Project Approach	Wendy Timms
8:12	3:12	Findings - levels	Wendy
8:20	3:20	Findings – quality	Wendy
8:30	3:30	Questions?	Ingrid / Wendy
8:40 am	3:40	Findings from grower survey	Ingrid
8:55	3:55	Key emerging questions about groundwater and monitoring	Ingrid / Wendy
9:05	4:05	Further questions	Ingrid / Wendy
9:15	4:15	Suggested options for the Future Data & Monitoring	Ingrid
		Overview of group session	
9:20	4:20	Group discussions & feedback	Ingrid / Wendy / Paula / George / Paul Dellow
9:50 am	4:50	Where to now?	Paula / George
10 am	5 p	Further questions, comments	Ingrid
10:10am	5:10 p	Close / Morning Tea	Ingrid

NB the agenda varied in start/finish times as the workshops were incorporated into a series of Namoi Water meetings.

Namoi Groundwater Monitoring
Grower Workshops
31 August and 1 September 2009
Summary of Discussions

Three workshops were held to present findings of the project to date and gain growers feedback on suggested future directions in groundwater monitoring. These workshops were held jointly with Namoi Water's AGMs. Thanks to Namoi Water for arranging the meetings.

Wednesday 31st August
* Zone 3 of Upper Namoi – 4pm in Gunnedah

Tuesday 1st September
* Lower Namoi - 8am at Wee Waa Bowling Club
* Upper Namoi (all zones) - 3pm at Gunnedah Services Club

Workshop Aims

The purpose of the workshops was to present preliminary findings of the monitoring project and gather ideas for future monitoring.

- Grower results – individual grower bore sample results were made available and aggregated findings presented.
- Groundwater level
  - maps showing general areas of groundwater drawdown to 2008 for Lower Namoi and Upper Namoi aquifers
  - these are a 2D regional scale agglomeration of results, in draft form.
- Groundwater salinity
  - agglomeration of average grower sampler data for groundwater salinity (no individual bores or properties will be identified)
  - comparison of results from samples that growers collect, with samples collected by WRL and others at monitoring bores
  - salinity results for monitoring bores – graphs showing changes over time since 1980s
  - maps showing where groundwater salinity is freshening, or more saline, or is not changing over time
- Discussion and gathering of grower ideas on
  - what changes in groundwater salinity could mean
  - how to set targets for groundwater salinity
  - how to monitor strategically in the future

The workshops were not addressing issues such as groundwater usage and allocations, water sharing plans, groundwater dependent ecosystems or mining issues.

The workshops were facilitated by Ingrid Roth and recorded by Paul Dellow, GHD Hassall. Thanks to Paula Jones, George Truman, Wendy Timms and Michelle Kelly for assistance with recording group discussions.

Background to Project

In outlining the background to the project, Paula Jones (Cotton CRC) explained that:

This project sought to benchmark water quality in the Namoi Valley and to also examine how investment is impacting on water quality. The Cotton CRC in conjunction with Namoi CMA commissioned this project with the project having two main components;

1. Come up with a framework / method for benchmarking and water quality purposes.
2. Social Component which seeks to examine grower's willingness to provide monitoring information. It also looks at the social elements of how data might be used and how grower data can be included in the program.

Project Approach and Findings

Wendy Timms (UNSW WRL) gave an overview of the sampling process including new data gathered, existing data review and groundwater user sampling. In outlining the results, Wendy addressed; the need for monitoring, groundwater level changes, aquifer connectivity, salinity changes and groundwater sampling. In relation to the need for monitoring Wendy explained that things change over time and that a good data set is required in order to assess natural variability.

The condition of the catchment and the programs to monitor were also discussed. The WRL testing focussed on groundwater levels and salinity as they were unable to cover all areas (e.g. did not cover nutrients or agricultural chemicals).

This part of the project had two facets;

1) The WRL testing of monitoring bores across the Namoi and

2) Groundwater sampling in July where groundwater users sent in samples.

Wendy also outlined there is a difference between monitoring and pumping bores in the way they are installed. Pumping bores have multiple screens and can cover several aquifers. Monitoring bore by comparison targets a specific aquifer unlike pumping bores.

A method needs to be established to define low and high connectivity between shallow and deep aquifers, so that 3D data can be divided into 2D maps of the shallow and deep aquifers.

Questions were also asked about the publicity of sampling and there are PR issues about getting the information out there. CMA requires a structure to see how groundwater levels are changing over time. It takes two years to get quality data for the five year review.

'It is the start of a couple of groups getting together and the CMA to better invest in the future. Back in the 80's [users] had to sample for licence renewal. Since the 1990's quality stuff has disappeared.' – John Clements – Namoi Water.

Findings from Grower Survey

Ingrid Roth outlined the findings from the telephone interviews of groundwater users and what we can say about knowledge, data availability, and interest in community monitoring, other concerns or issues. Ingrid and Wendy also addressed a number of common questions.

Questions and discussion about groundwater and monitoring

Discussion was held as a whole group during and after the presentations. The options were then considered in more detail through small group discussions.

Monitoring water quality

- Is there a possibility of adding EC meters to telemeted monitors on monitoring bores?
    - This is not so suitable on monitoring bores as the water is stagnant but it may be suitable on the telemeted irrigation bores. There would be additional cost in purchasing the meters but relatively little additional on-going cost.
- There is a feeling that there needs to be a lot more data on quality. This is quite a grey area.
- Wendy spoke the need for growers in Zone 3 to have the capacity to self manage their own monitoring of bores. These users saw that it was important to monitor quality in order to find out if the groundwater is suitable for what you are planning on using it for. The following response was put forward as an advantage of groundwater users being able to self monitor their groundwater resource.
    - *'It could give you early warnings in relation to the groundwater getting too saline and also allow you to be more powerful as a manager of water to make operational decisions.'*
- It was also mentioned that through monitoring quality they could modify their crop for the next season if they saw a trend that worried them.
- *"Monitoring is essential in order to get data for 5-year reviews."*
- Ross Beasley DECCW explained that the monitoring bores across the Namoi Catchment target specific aquifers where as pumping bores can vary across aquifers.
- Growers want real information and want to know if quality is changing (ie dramatically, relatively, trends and do not want snapshots).
- *'Need to have both a spatial distribution over the catchment as well as temporal change.'* (UN Gp.2)
- One group in the Lower Namoi felt that it was important that there was some consistency in the terminology which the laboratory and the department use to report their results. They made mention of the following terms; EC, Salinity and sodicity[2].
- One of the Upper Namoi groups commented that there is a fair bit of discrepancy occurring within zones in relation to the groundwater table. *'It is rising in some parts of zones and falling in other parts.'* This may present conflicting messages when defining groundwater levels in each zone.
- *'It is good to know what is happening in your own area. This is important.'*

Information accessibility

- Need to get data; levels are there we just need them compiled and delivered.
- The CMA would be willing to coordinate the monitoring of data if growers handed the data to them. A number of growers indicated that they would prefer the department to continue to do the monitoring but if the department was unable to coordinate the monitoring of data than another agency/ authority should undertake this.

[2] *These are different parameters - salinity refers to total salts, but has several different methods of measurement including TDS (total dissolved salts) and EC. EC is the electrical conductivity, or field estimate of salts using an electrode meter. Sodicity is the sodium content.*

- Hydrogeologists also want the data to get out there; however there are issues with quality assurance and quality compliance. The Department have let the data slip.
- Used to be some of the best monitoring ever, *'sad that it's slipped.'*

Data communication and presentation

- There was concern in the Lower Namoi that it creates a negative perception around using the terms *'3rd highest salinity'* in presenting results from the grower samples as this may be misinterpreted by some people elsewhere.
    - *'The words used don't make a good operational outcome. Not only the information but how methodology goes around as it can be quite misleading 'terms like manipulation.' 'Manipulation – 'real fear about this stuff.'*
    - *"It does matter in terms of what data will be used for. Need to ditch the rank."*
    - John Clements – *'for the purpose of the data, decision makers decide on sentences. So the language is very important. They will only look at the average.'*
    - *'Ditch the rank.'*

- Upper Namoi growers expressed concern over the averaging of results across zones due to the differences that currently exist. They were also concerned about who would use this information and how it would be reported.
- The Lower Namoi Gp.1 also expressed concern over growers contributing their own data to a coordinated monitoring program as the *'pooling of data can be dangerous.'* It is difficult to compare between properties/locations and concerns were expressed over the reliability of sources.

Other issues

- Subsidence is not being looked at. *'It is a hard thing to show'* and also relates to a 'money/funding issue.'
- Subsidence in the lower Namoi is expensive to monitor however new satellite methods are being established to monitor surface levels.
- A number of growers felt that the department had not been very active in the monitoring of groundwater in recent years. *'We don't think anything is happening at the moment.'*

Grower sampling

- Groundwater users in Zone Three commented that a user participation in a coordinated groundwater monitoring program would enable users to react in a responsible manner in obtaining and recording their data. The information that the growers supply would directly benefit them as the data they supply would assist them in making better informed decisions for their farming enterprises.
- Some Lower Namoi groundwater users already keep a record of the quantity of water used each year however they do not necessarily keep a record of the level of their bores.
- Questions were asked in relation to the difference in quality that may come when groundwater had been pumped to a storage and been there for 3 months. Wendy Timms responded that the pH and alkalinity will change due to interaction with the atmosphere. There had been projects carried out in the past which had sampled storages.
- Users in the Lower Namoi had concerns about the reliability of the data from the sampling process and believed that shallow water may get into the bores and skew the average. The output obtained may not be truly reflective of that bore, as shallow water may *'drive that figure up!'(LN)*
- Groundwater users in the Lower Namoi felt that it was important to look at EC and break that up into the different aquifers.
- Lower Namoi (Group 3) also believe that there needs to be a central coordinated system where groundwater users can submit their monitoring data to so that there is some form of consistency in the way in which it is analysed.

Timing of sampling:

- It is very expensive for those with electric pumps to sample in July as you trigger a minimum charge in turning on the electric pump (e.g. $800). Those with diesel pumps noted it is also costly and time consuming for them to start up and purge pumps.
- Although July is considered to be the period when groundwater is most stable, there was concern that sampling in July is not representative of what is being put on the crop. These growers were more concerned about the quality of water going on the crop rather than trends in the off-season. It was felt that sampling needs to be done during the season or if not before and then again after.
- One user suggested that you should '*Sample while you are irrigating, preferably in December or January'*
- It was concluded that grower samples would be far more feasible at the start and end of the season - to avoid electricity charge and so the water quality is closer to that being used on the crop.

Comparability

- Groundwater users in the Lower Namoi indicated that a methodology should be developed so that the monitoring of bores is consistent among groundwater users.
- They felt it was important to have consistency / comparability of results from water quality testing.
- They noted there could be a lot of variation between different laboratories and that for comparability growers should all have their samples tested at the same Lab/Department and also follow a consistent process for monitoring.[3]
- This methodology should include things on how to measure both water levels and quality and indicate a time period for when sampling should be undertaken.[4]

[3] *All laboratories that are NATA registered and provide an ion balance less than 5% are considered to provide reliable results that are comparable between laboratories.*
[4] *The factsheet "DIY Groundwater Monitoring" providing this information is on the Cotton CRC website. Further information will be provided by the final report of this groundwater monitoring project.*

Preferred options for the future and data monitoring

Potential options for groundwater monitoring had been developed based on the surveys and discussions with the project team, Cotton CRC and Namoi CMA. These were presented to the workshop groups as:

1. Enhanced data gathering/ communication by the Department
2. Telemetry on a representative sample of bores – real time data available
3. Supplement with:
    a. additional independent data gathering from monitoring bores
    b. additional independent data gathering from grower pump bores
    c. coordinated program of monitoring by groundwater users of their pump bores
4. Groundwater users keep a log of own bores and seek advice if a significant variation occurs
5. Supplement with independent analysis/ communication
6. No change.

All workshops considered preferred future options and offered comments on the merits of each option. Most groups prioritised their preferences. Zone 3 noted that it is influenced by the available budget '*Give us a budget and we will choose'.*

Even within a region, different discussion groups had different priorities. It was concluded that it may need to be a case by case basis to suit each zone / sub-group. The Lower Namoi groups had similar preferences whilst the Upper Namoi groups were quite varied. Comments below are coded according to the groups (eg LN Gp3 is Lower Namoi discussion group 3).

Summary of priority options

Group	High Priority	Moderate Priority	Not Worth Pursuing
Zone 3*	Department, Telemetry	Additional independent data gathering Users keep log of their own bores	Independent anlaysis /communication
Lower Namoi #	Department Telemetry Users keep log of their own bores	Additional independent data gathering.	Supplement with independent analysis
Upper Namoi 1	Department	Telemetry	
Upper Namoi 2	Telemetry	Additional independent data gathering	
Upper Namoi 3	Department and Telemetry		
Upper Namoi 4	Department	Coordinated program	

*Zone 3 felt the options were listed in priority order with 1 being highest priority through to 6 as the lowest and the top 4 being the most important.

#The Lower Namoi wanted a consistent methodology developed so that they could monitor and keep a log of their own bores and compare results with other groundwater users in their area.

The Upper Namoi growers all agreed that a high priority was for the department to continue monitoring which would be aided through the introduction of telemetry. They varied in their views about a coordinated program – some groups thought it would be valuable while others thought that additional independent data gathering was required. They felt that different approaches could be used in different areas.

1. Enhanced data gathering/ communication by the Department

This was the highest priority for all groups.

All three workshops expressed similar concerns about the monitoring of bores by the department and felt that more information could be provided in relation to the monitoring of both levels and quality by the government. Many also believed the 'roadshows' which the department used to undertake were quite beneficial and were a very useful way of being updated in relation to the current status of the groundwater condition.

- When discussing with one of the Lower Namoi groups about the role the department has in data gathering and then communicating this data, they made mention that the department has been affected by resourcing issues in recent years and in relation to the collection of data they believe the *'department is not doing it.'* (LN Gp 1) They also made mention that the Department has been suffering from labour issues in being able to obtain this data. (Gp.1)
- Upper Namoi also had similar concerns about the resourcing capacity of the Department. *'There needs to be a way of getting resources to the places where they are required. There is no regional DWE Director. Hydros are not in a position to take a stand. The other issue is there enough Hydros to do the testing. It comes down to a resource issue that is now three years old.*'
- Need to have access to monitoring bores and data needs to be made available.
- The Upper Namoi group argue that there is a lot of cynicism around the way the Department has gone about monitoring of and communicating information surrounding the groundwater. One user also stated that they thought the *'department has given up.'*
- All three workshops believe that the Departmental 'roadshows' were a beneficial way to communicate with groundwater users and that these should be reinstated and even offered thoughts on other topics that could be included. *'Historically road shows never involved quality. Future ones need to involve quality.'* (LN Gp.2)
- Telemetry is still in an early phase and only limited to a number of bore sites. *'We need to reinstate the roadshows and put someone in the room to interpret the data.'* Telemetry however focuses on groundwater levels and not salinity. (Zone 3)
- Zone 3's preferred option is **enhanced data gathering / communication by the Department.** This will also be supported by **telemetry** once it comes on board. Telemetry will be great once we get it up and running however we can't decide until we see it up and running. We will also need to see the five year trend. Just looking at a graph and a snapshot is not ideal.
- They also believe that there could also be a combination of options 1-3, however probably not 3a). Need to be smart with resources and combination of options. Need to co-ordinate grower sampling programs.
- In relation to telemetry, Zone 3 argues there are a number of technical aspects to overcome and data logging needs to be implemented. They also made the suggestion to have an EC meter logging the same time as water logging. Once set up the operational costs wouldn't be that much more. The capital costs are more expensive. Do we also know enough on the system in relation to aquifer height and salinity.
- The Zone 3 groundwater users also believe that Salinity (EC) is not the only thing that should be monitored. *'There are different things we should be hacking into. It is not that simple.'*

2. Telemetry on a representative sample of bores – real time data available

Groundwater users saw telemetry as a positive step forward and greatly valued the prospect of being able to access real time data. Concerns were expressed over the long term maintenance and monitoring of these sites and the information not be that relevant to many users as telemetry was only on selective bore across the catchment. Ross Beasley from NSW Office of Water (NOW) explained the telemetry process and how it operates. He also mentioned that NOW had contributed $710,000 to ongoing monitoring and development and the National Water Commission had provided $682,000 to the project. Each telemeted site costs approximately $8,000 to equip.

The following comments were made in relation to the telemetry of bores;

- Who is going to fund the ongoing maintenance and monitoring after 2012. (LN Gp. 1)
- Telemetry will eventually need to be implemented on all test bores (LN Gp.1)
- Telemeted bores will *'Need to measure both levels and quality'* (LN GP.3)
- *'Telemetry system is very important – use of real time data.'*
- *'To be carried out on a certain number of bores'* and there needs to be a *'Good balance [of telemeted bores] across catchment.'* (LN Gp.3)
- There are only a limited number of sites (30 in total) across the entire Namoi Catchment, so this is still not an ideal representation of the condition of the groundwater.
- Concerns over long term continuation of telemetry program.

3. Supplement department data

- This was the top priority for LN Gp 3. who fel there is a real need around point 3, collecting and looking at data. (LN Gp.3). They felt that data should be collected at an individual level and compared.

a. additional independent data gathering from monitoring bores

- *'Identify bores that are used'* (LN Gp.3)
- Upper Namoi (Gp.2) indicated that the monitoring bores may be more reliable than the pumping bores in order to carry out additional independent data gathering on.
- Lower Namoi (Gp.3) rated point three as a medium priority and if there was to be additional data gathering from monitoring bores then there would be a need to identify the bores that are used.
- The Lower Namoi (Gp.1) also believe that monitoring could be supplemented by additional independent data gathering from both monitoring bores and pumping bores, however stressed that there would need be '*faith in the testing.'*

b. additional independent data gathering from grower pump bores

This option was intended to be about the potential for an independent person/organisation to take readings, gather and analyse samples from grower bores. There was very little discussion around this with most people focussing more on growers collecting samples – which is discussed in the next option.

- Concerns about how the data in point 3 might be skewed and some pipe 1 data will be different to the rest of the zone. Geologically it looks different to zone 3. There is also the uncertainty of people being involved and concerns that *'this data may fire back on us,' 'need to clean up skewed data,'* and *'get data cleaned and qualified.'*
- For consistency and quality assurance one of the Lower Namoi Groups believe that *'All samples need to be sent to the same lab.'*[5]
- DECCW should also undertake sampling during the pumping season so that results can be compared between monitoring bores and pumping bores.

[5] *This should not really be necessary as all laboratories that are NATA registered and provide an ion balance less than 5% are considered to provide reliable results that are comparable between laboratories.*

c. coordinated program of monitoring by groundwater users of their pump bores

Across the Namoi, users actively monitor their levels and make their decisions based on their own monitoring information. There was concern about a coordinated monitoring program. Many did not have the equipment to monitor quality and expressed concern over the time it would take to monitor groundwater and also saw more value in monitoring at the start of the season and then again at the end.

They did not necessarily want to start their pumps up in July as they did not want to trigger a demand charge on their electric pumps and did not want to waste water in order to obtain a sample (UP Zone 3.).

The following comments were made in relation to the option of groundwater users participating in a coordinated monitoring program:

- There would be a huge response if done in September as people could get into a routine of sending in the first sample. This approach will also require trust – what will it be used for. Also if the bores are on, then people will collect a sample.
- Data will also need to go through a quality assurance program.
- Zone 3 felt that it was important if this option was to succeed that it would be vital that growers trusted the process as they wouldn't want to provide any information then have it fire back on them.
- *'Growers need to supplement data with their own to link production bores with government bores.'* (LN Gp.2)

- *'It won't work'*
- *'I wouldn't operate without having this information myself….but wouldn't submit it.'*
- Many users indicated that they have got their own data and know what is happening on their farm in relation to the groundwater condition.
- *'Option 4 is important for individuals but is option 3c really important'*
- One farm spoke of the data set they have on their property which they have been collecting over a number of years and spoke of the benefits of keeping this data.
  - *'We know what water use we are putting on and to know what changes are required.'*
  - *'With the mines we are increasing the testing on the farm…we will then be able to prove that the mines caused the problem.'*
  - *'If we saw changes then we would be able to do something.'*
  - *'If bores collapsed, we could put a new one down, plug the bore or put a camera down, we do maintenance every five years. There is a number of things we could do.'*
- Users in the Lower Namoi indicated that they would be happy to talk with their neighbours about groundwater monitoring and to share their data with neighbouring landholders. However they were reluctant to submit data to a coordinated program.
- Use of EC meters[6] and CMA Website.
- Some users raised the idea of the timeliness of such a program.
- One Lower Namoi group insisted that for this program to succeed that there needs to be a coordinated collection program and data should not be compared between properties. Further information is also required on the reliability of the sources and locations and it could be beneficial to do a quality assurance on the data.

---

[6] *Growers can borrow EC meters from the CMA for water salinity testing.*

4. Groundwater users keep a log of own bores and seek advice if a significant variation occurs

Many groundwater users already monitor their own bores. Most users already monitor levels. Quality is measured less frequently, however many indicated that they would know if quality varied. Users would feel more confident in keeping a log of their own bore(s) if there were templates / guidelines in place so that records were consistent.

- A Zone 3 user indicated that *'this approach will not be consistent enough and many will not want it'* and *'Users already keep their own records.'* They indicated that users already sample their own bores. *'We measure each individual pipe'* and it should be looked at on an aquifer by aquifer basis.
- 'Need a standard applied. Rather than time of pumping should be volume of water pumped.' (UN Gp.3)
- For this option to succeed there needs to be trust in the process and more samples need to be used and also need to be careful about the way the information is conveyed and presented (LN Gp.1)
- Perhaps there could be templates and instructions set up so if individuals wished to, they could have some guidelines about the best way to monitor and record their results. (LN Gp.1) *'Guidelines need to be established so that growers can do their own monitoring.'* [7]
- *'Need to have this and need to sort out who subsidises who for information.'* (LN Gp.2) 'Important.'
- Group 3 had a lot of discussion surrounding this point as growers already keep their own log.
- *'Is there a payment for collecting/sampling.'*
- Important need for them to collect that.
- *'Sampling will need to be done in July / January'* (LN Gp.3)
- Standardise in January – all done at the same time.
- *'Sampling in July won't work as we don't want to trigger a demand charge with electric pumps.'* (LN Gp.3)
- *'Data needs to go beyond farm and look at how they [the aquifers] are all connected.'*
- Concerns were also raised over who is going to be responsible for the management of the data and managing the repository
- This is good for individual use however questions remain over the consistency of the program.
- Some groundwater users also expressed concern that they do not have sufficient time to do this and also that physically it was impossible to monitor their bore as some had *'no facility on bore to monitor and the casing is closed on top.'*
- The Upper Namoi group believes there is some interest in this, however there has not been a lot done in the past.
- Users indicated that the data they collected through a co-ordinated monitoring program will improve with increased rainfall across the catchment and through using their bores less. A number indicated that they wanted to see graphs proving this and also would like to receive information on monitoring in relation to specific locations across their zone.

5. Supplement with independent analysis/ communication

Concerns expressed over quality assurance / quality check and that results may vary between laboratories.

- Water quality testing needs to be done by experts and then standardised.
- Not be a problem if carried out by an independent hydrologist who quality checks all the information.

---

[7] The factsheet "DIY Groundwater Monitoring" providing this information and a template for groundwater records is on the Cotton CRC website. Further information will be provided by the final report of this groundwater monitoring project.

6. No change

- All groups agreed that changes were needed to improve monitoring and data communication.